6.622 Power Electronics *Prof. David Perreault*

Lecture 14 - Isolated DC/DC 2

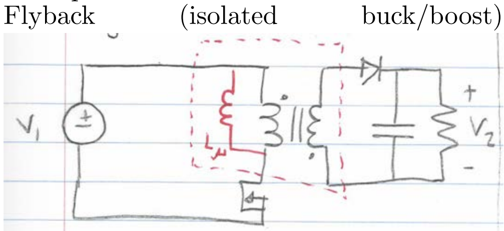
1 Review

Isolated converters provide:

1. Galvanic Isolation
2. Large conversion ratios
3. Ease of multiple outputs

Examples:

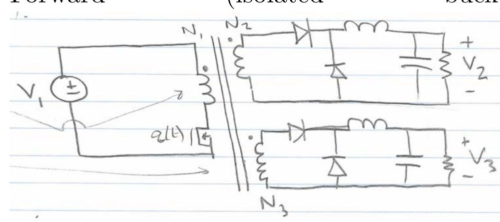
Flyback (isolated buck/boost)



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

Gapped <u>flyback transformer</u> serves as energy storage element (L_μ acts as inductor)

Forward (isolated buck)



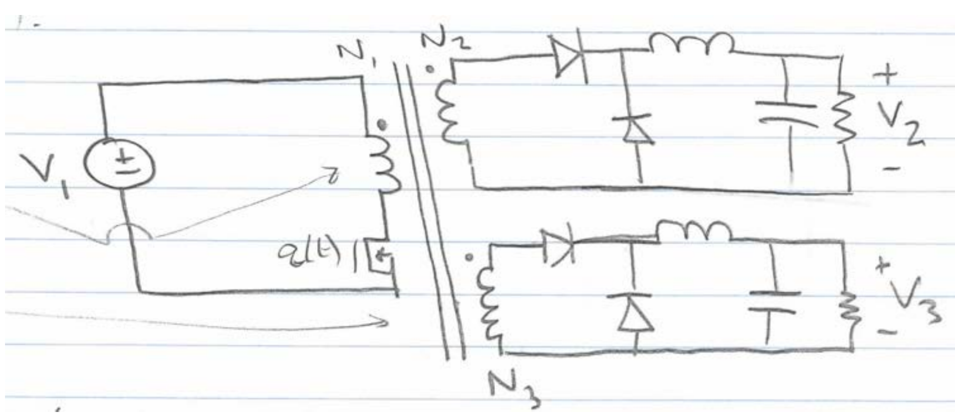
$$\frac{V_2}{V-1} = (\frac{N_2}{N_1})D$$

L_μ is an <u>undesired</u> parasitic. We must add <u>extra</u> circuitry to <u>reset the core</u>!

2 Multiple Outputs

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

e.g. forward
Needs reset mechanism!
Series-wound core!



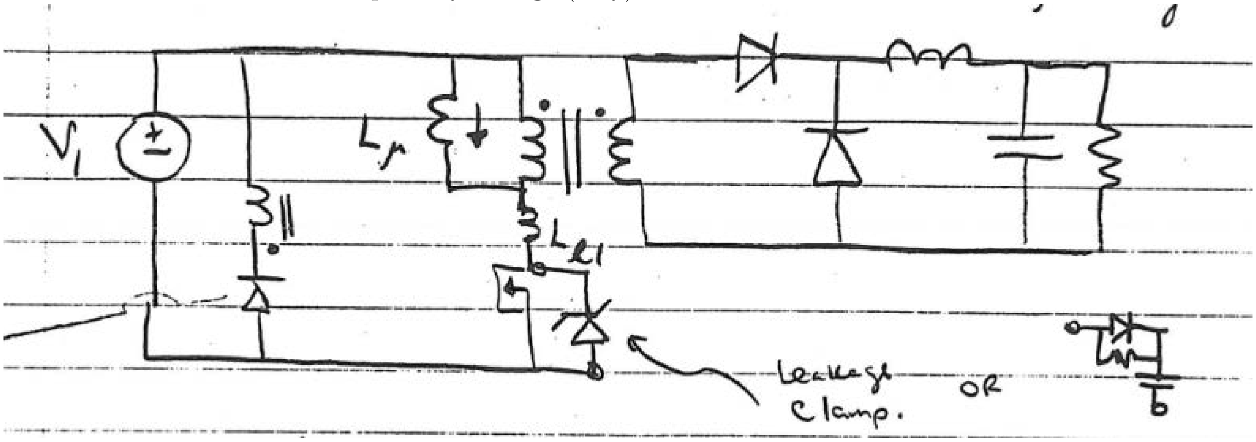
<u>Ideally:</u>

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

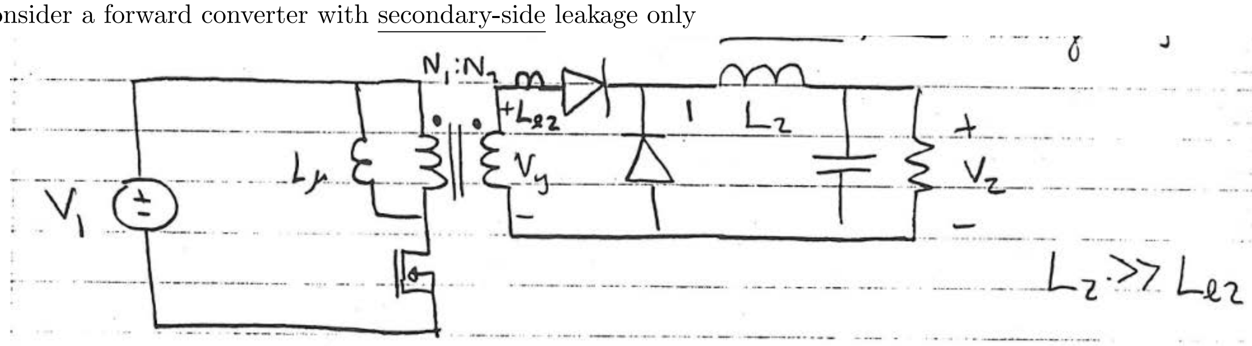
- This can give us (many) multiple outputs with only modest increases in complexity

3 Transformer leakage inductances

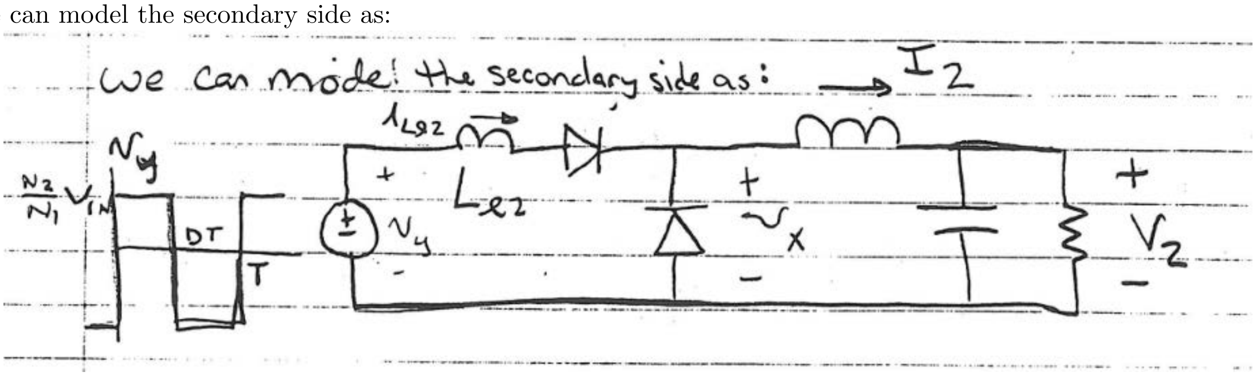
Leakeage inductance parasitics also influence operation:
Consider a forward converter with primary leakage (only)



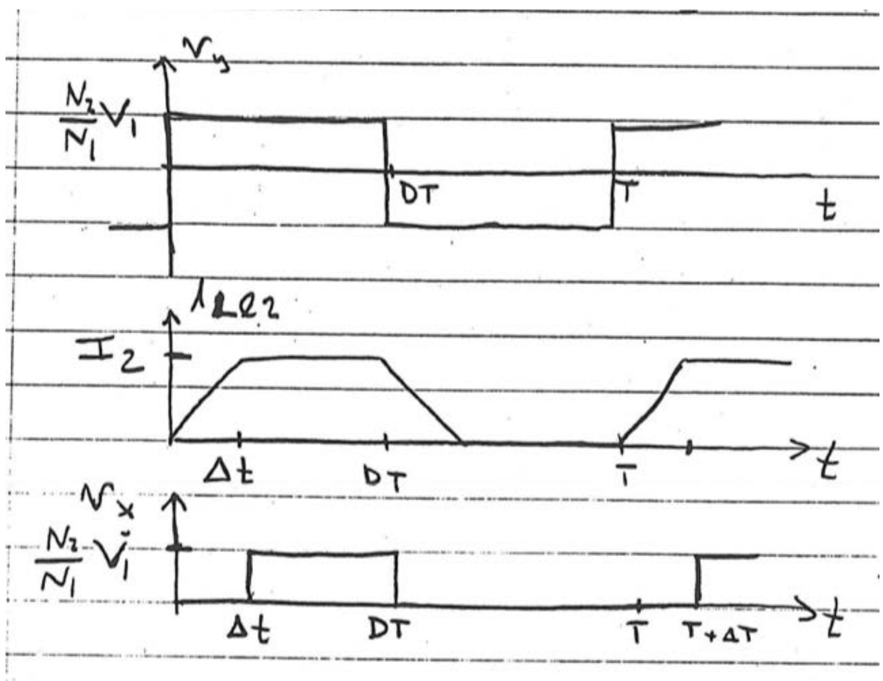
When we turn off the main switch, the reset winding can handle magnetixing current/energy, but <u>not</u> primary-side leakage inductance. We may need to add additional circuitry to absorb or recycle this energy! (e.g. Zener)
Consider a forward converter with <u>secondary-side</u> leakage only



We can model the secondary side as:



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!



$$v = L\frac{di}{dt}$$

$$\therefore \Delta t = \frac{L_{l2} I_2}{(\frac{N_2}{N_1})V_1}$$

$$V_2 = < V_k > = \frac{N_2}{N_1}(D - \frac{\Delta t}{T})V_1$$

So we may calculate the conversion ratio as:

$$\boxed{V_2 = \frac{N_2}{N_1} D V_1 - \frac{L_{l2}}{T} I_2}$$

So the conversion ratio now not only depends on duty ratio, but load current

- We will have to increase duty ratio as load increases
- This is called load regulation! (as with rectifiers)
- Maximum D increases, increasing device stress

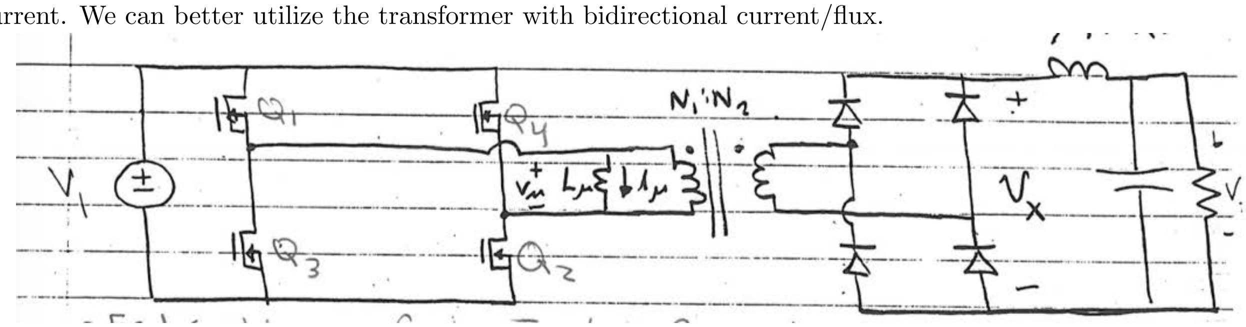
This becomes very important with multiple outputs.

- We can only adjust D to regulate one output
- since conversion ratios now depends on load currents, the output voltage 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" and is undesirable!

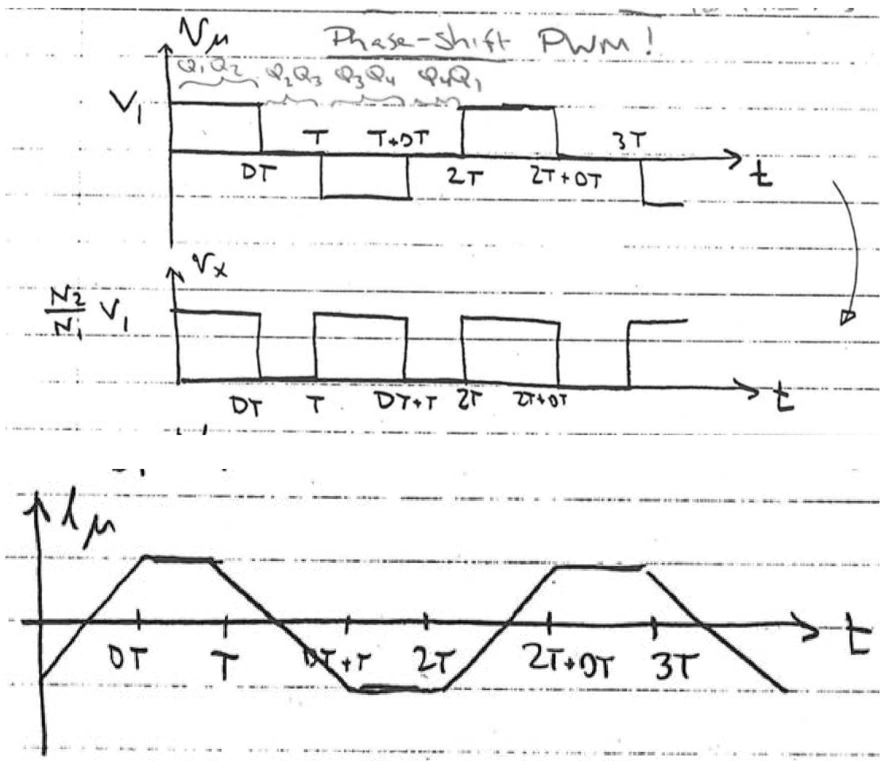
∴ the transformer parasitics are important for isolated converter operation

4 Double-ended converters

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



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

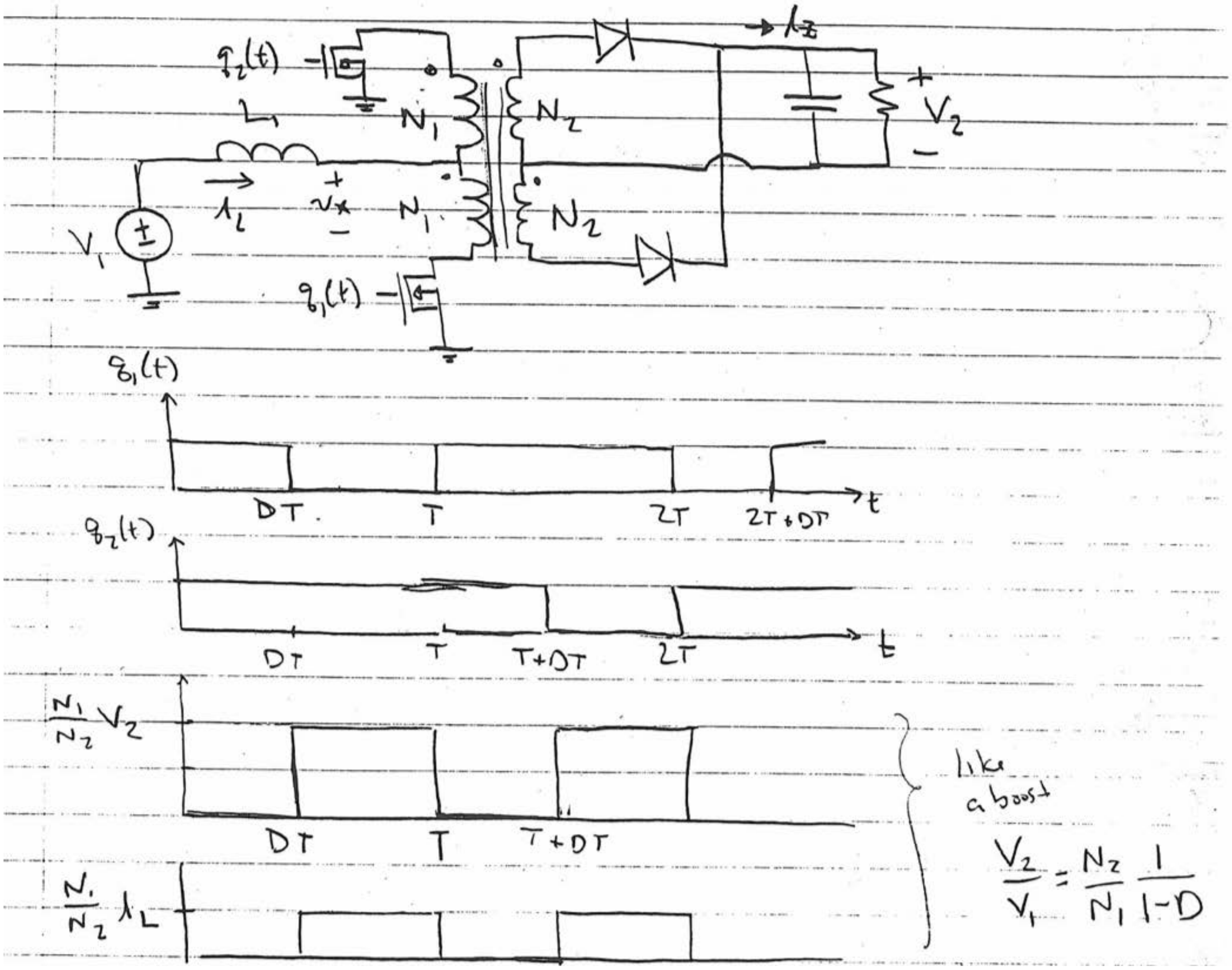


Fundamental ripple frequency doubles! (smaller filters, transformer)

Core flux swing is bidirectional $-B_{max}$ to $+B_{max}$ instead of 0 to B_{max}

- Bidirectional flux swing allows smaller transformer
- Frequency doubling allows smaller filter
- However, we must use <u>control</u> or a <u>blocking</u> capacitor to ensure that $< i_\mu > \; 0$, or we will saturate the transformer! (Tricky)

Many other kinds of isolated converter variatns exist!
e.g. current-fed push-pull (like isolated boost)



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