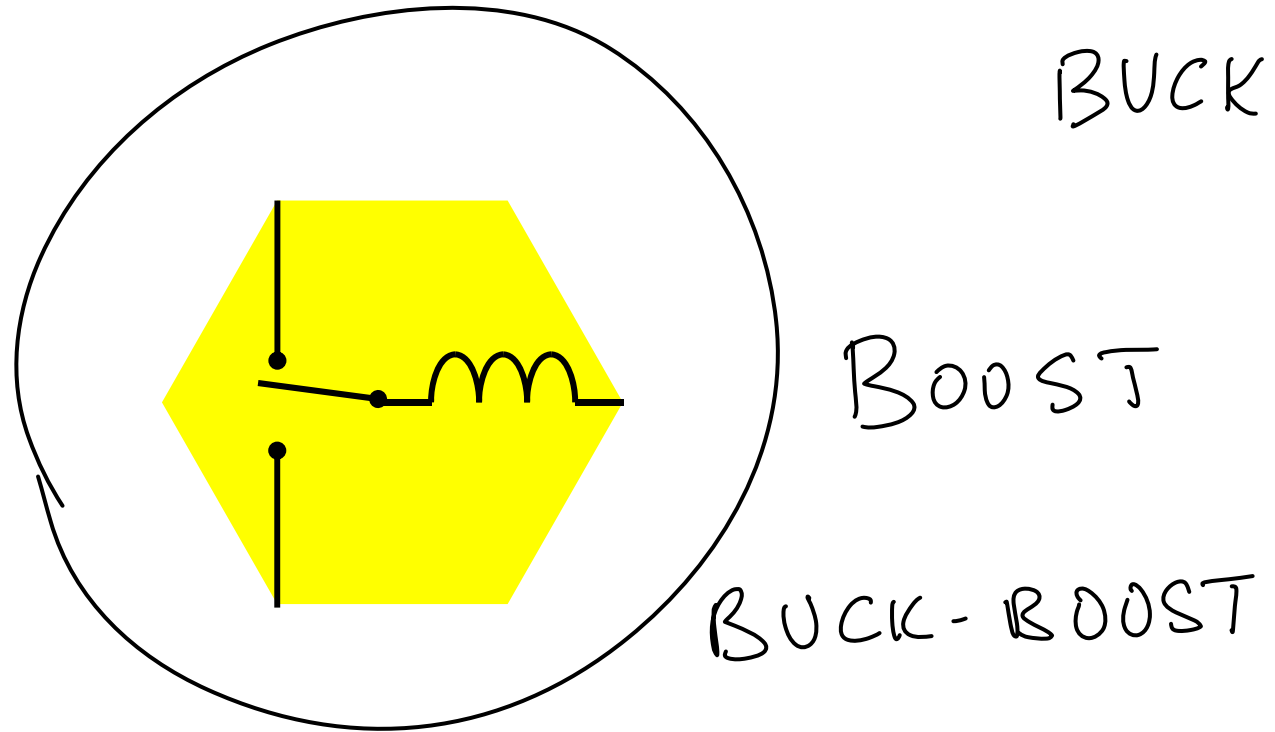


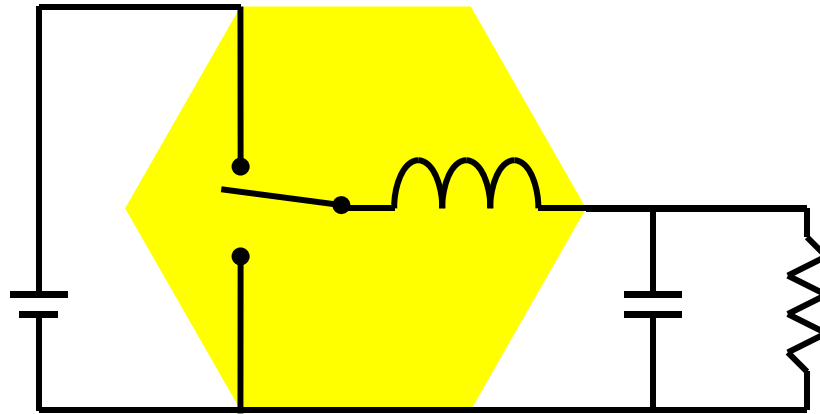
Switched Mode Power Conversion



Basic Converter Cell

Switched Mode Power Conversion

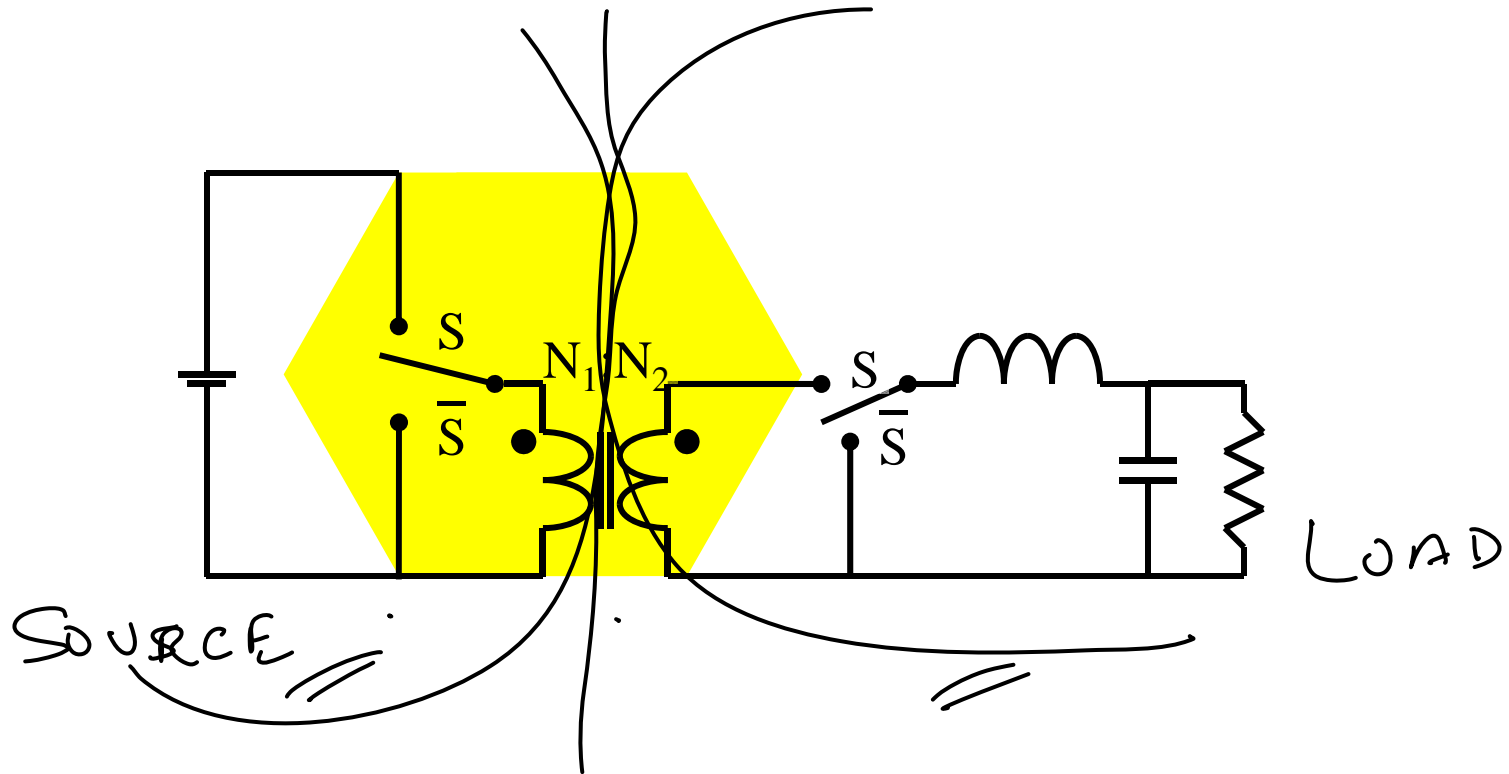
Non-Isolated Converter



Buck Converter

Switched Mode Power Conversion

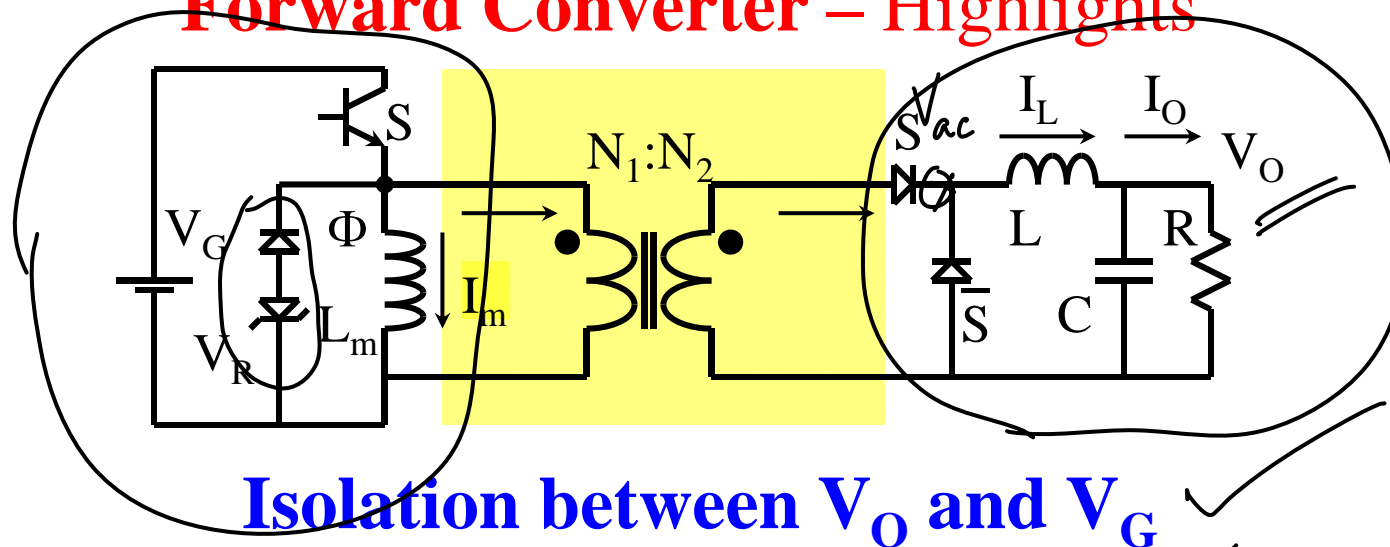
Isolated Converters - Contd



Electromagnetic Isolation

Switched Mode Power Conversion

Forward Converter – Highlights



Isolation between V_O and V_G

Maximum Duty Ratio: 0.5

Magnetic Core Utilisation: 0.5

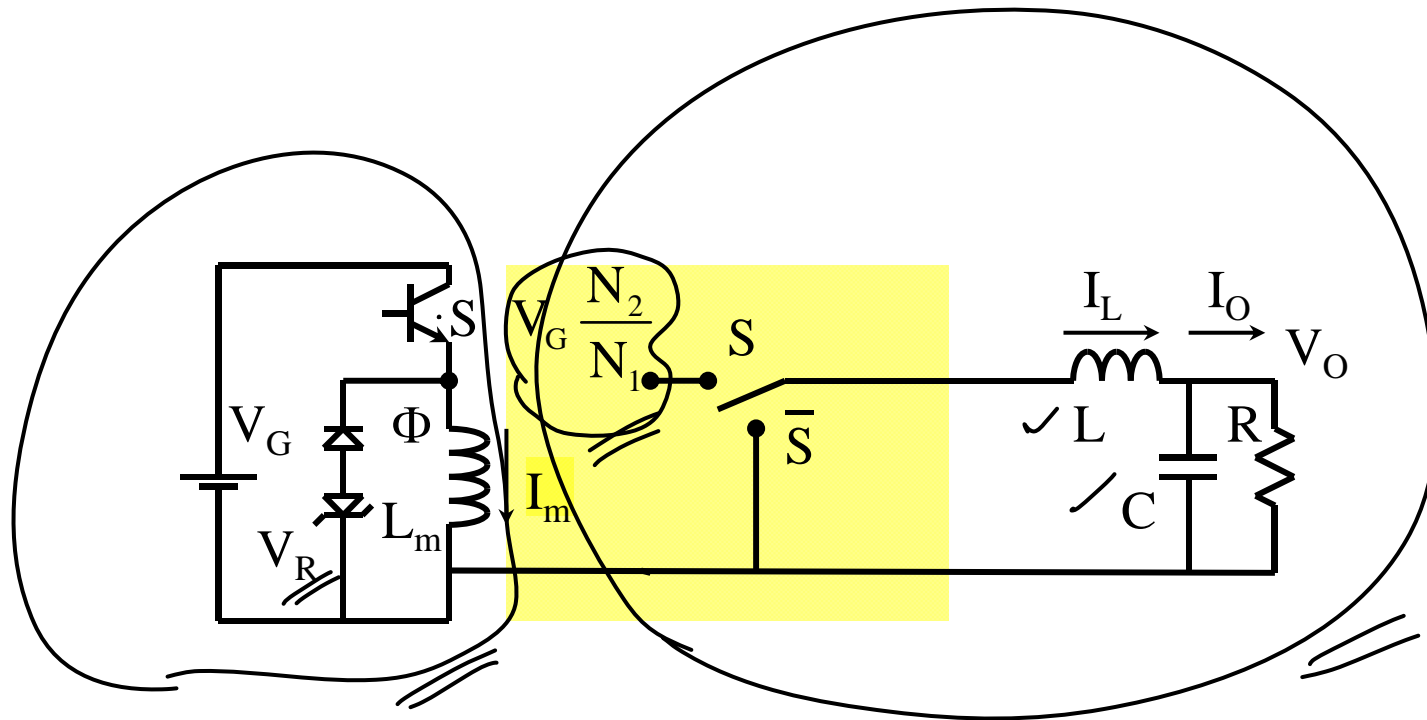
Conductor Utilisation: 0.5

Circuit Voltage: 0.5

Additional Magnetisation Loss

Switched Mode Power Conversion

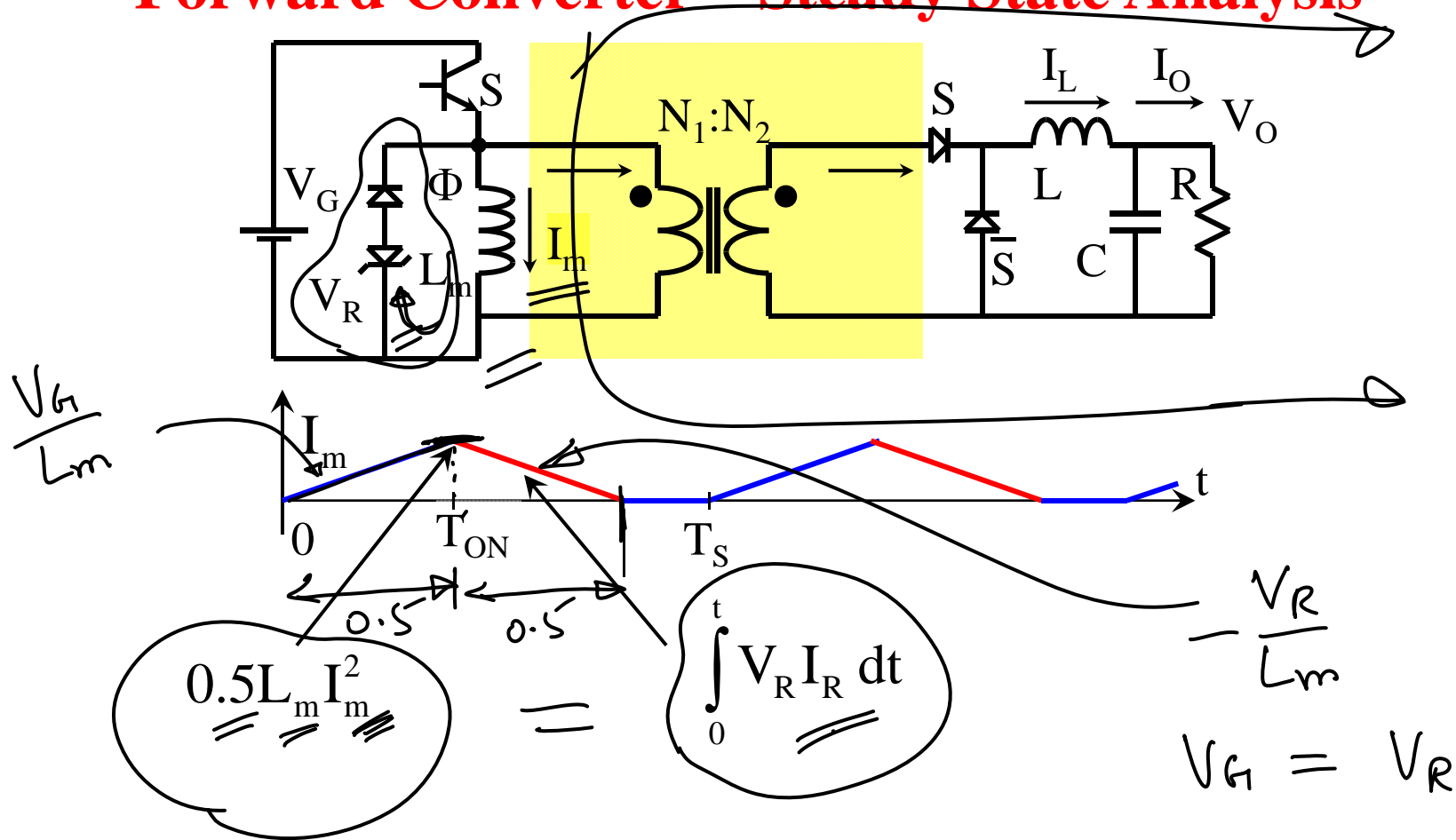
Forward Converter – Non-isolated Equivalent Circuit



Non-Isolated Equivalent Circuit

Switched Mode Power Conversion

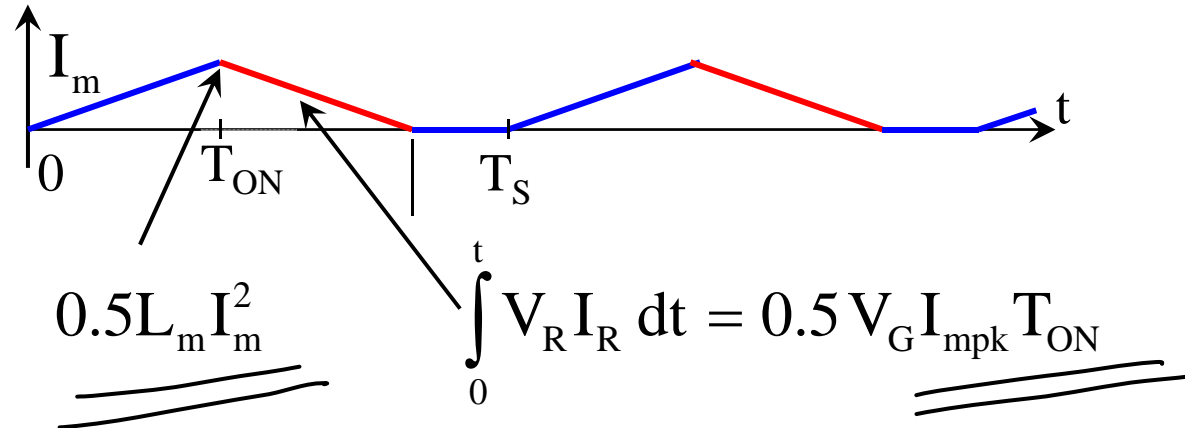
Forward Converter – Steady State Analysis



Magnetisation Energy

Switched Mode Power Conversion

Forward Converter – Steady State Analysis



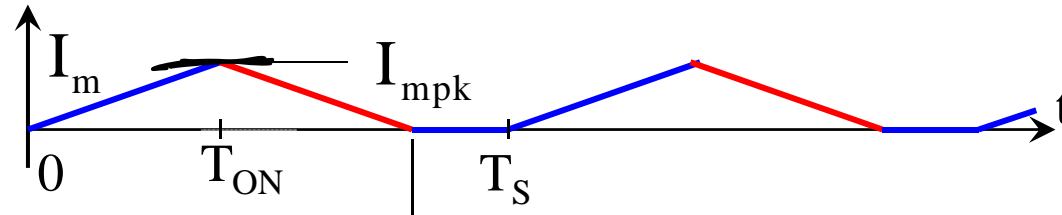
$$\text{Energy Loss per Cycle} = \frac{0.5 V_G^2 T_{ON}^2}{L_m} \text{ J}$$

$$\text{Power Loss} = \frac{0.5 V_G^2 T_{ON}^2}{L_m T_S} \text{ W}$$

Loss Per Cycle

Switched Mode Power Conversion

Forward Converter – Steady State Analysis



$$\text{Power Loss} = \frac{0.5 V_G^2 T_{ON}^2}{L_m T_S} \text{ W}$$

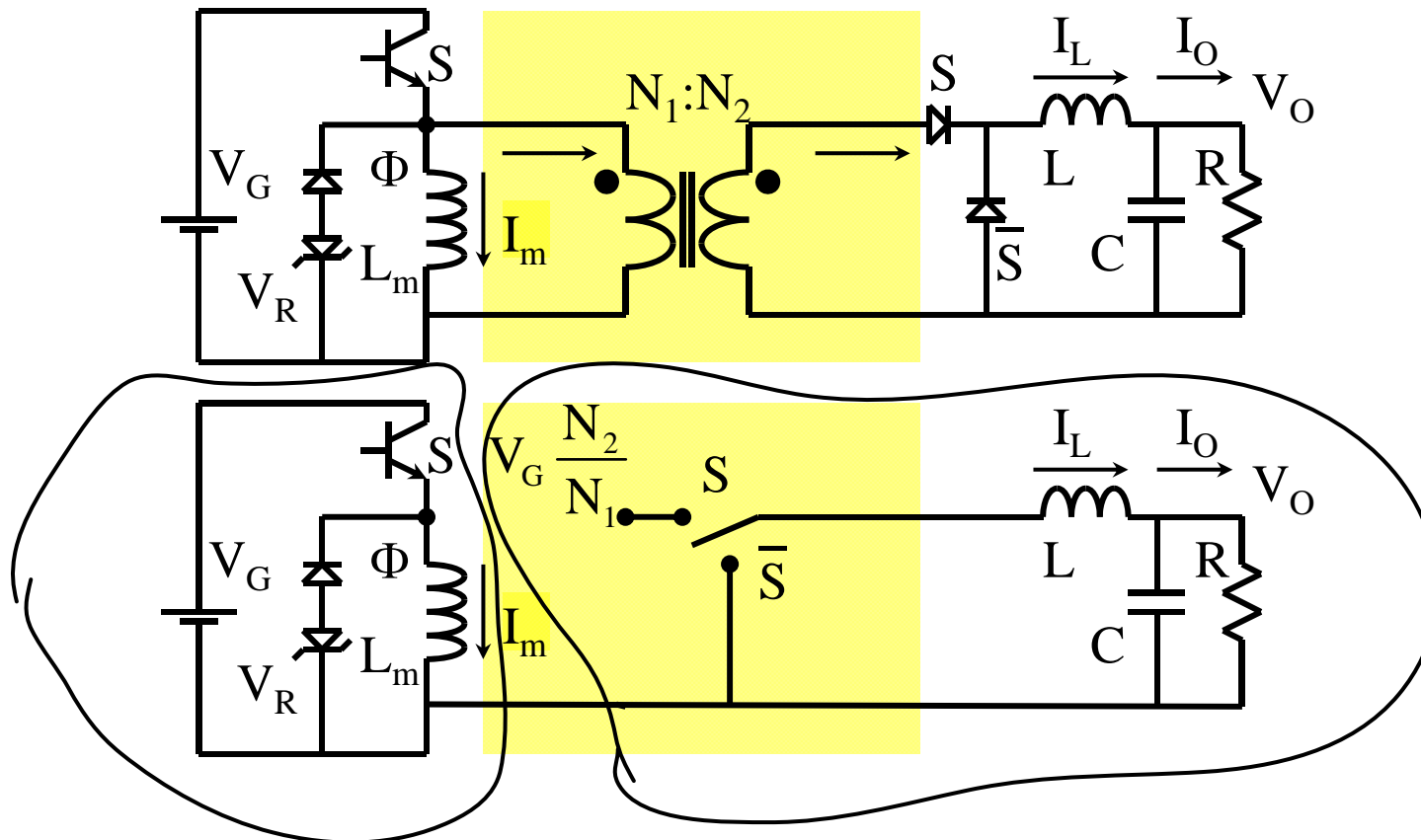
$$\text{Power Loss} = 0.5 V_G I_{mpk} D \text{ W} \quad \checkmark$$

$$\frac{P_{Loss}}{P_o} = 0.5 \frac{I_{mpk}}{I_o}$$

Magnetising Power Loss

Switched Mode Power Conversion

Forward Converter – Non-isolated Equivalent Circuit

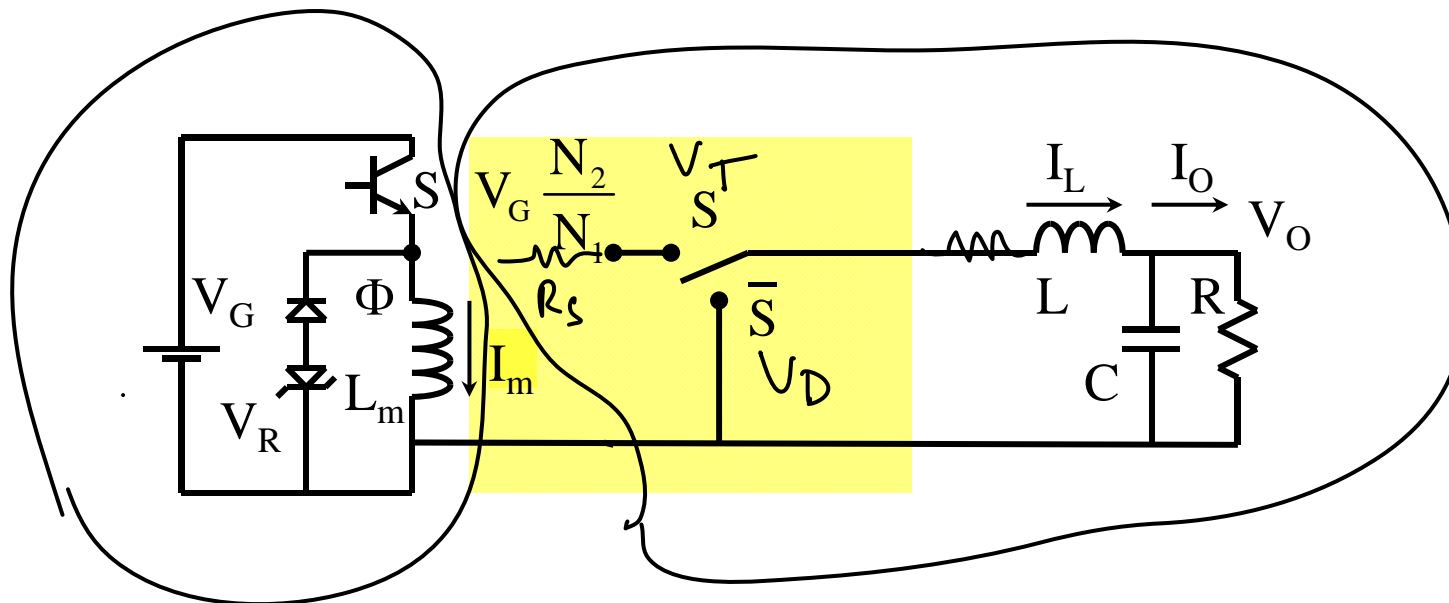


Non-Isolated Equivalent Circuit

Switched Mode Power Conversion

Forward Converter – Non-isolated Equivalent Circuit

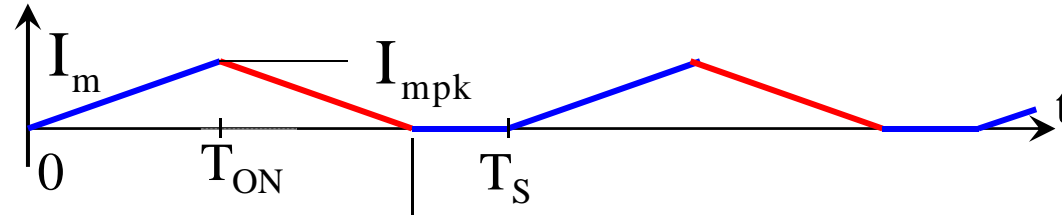
Effect of Switch, Inductor, Source Non-idealities
May also be Evaluated



Non-Isolated Equivalent Circuit

Switched Mode Power Conversion

Forward Converter – Typical Losses & Efficiency



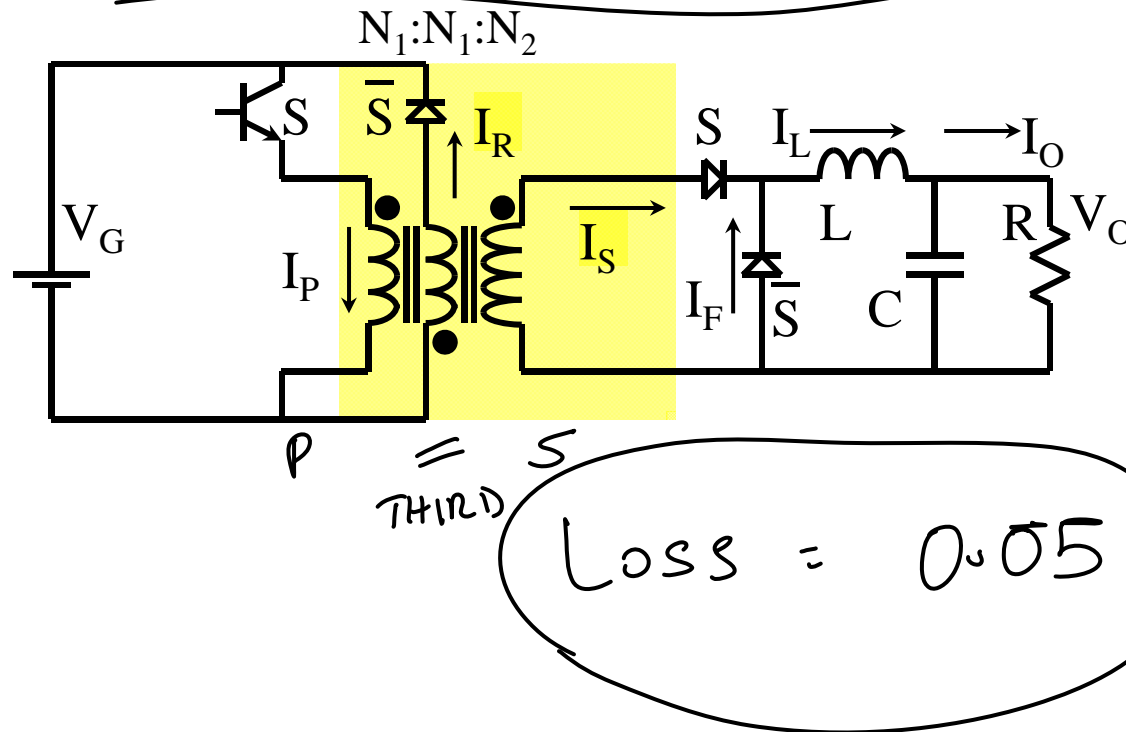
$$\frac{P_{Loss}}{P_o} = 0.5 \frac{I_{mpk}}{I_o}$$

$$I_{mpk} \simeq 0.1 \underline{I_o}$$

Typical Magnetisation Loss: 5%

Switched Mode Power Conversion

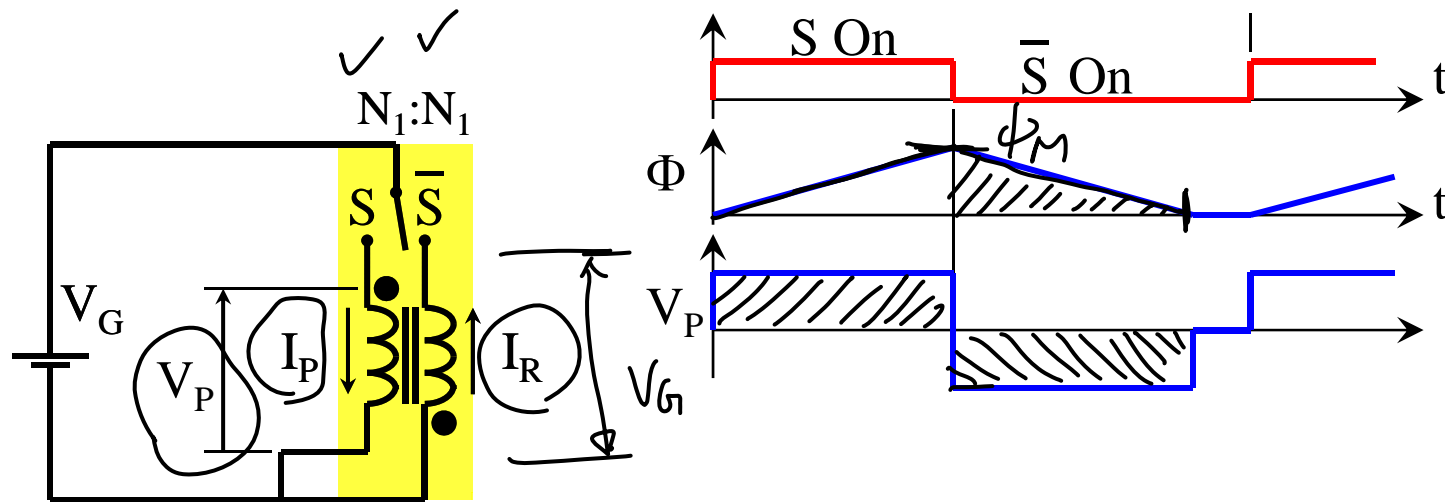
Lossless Forward Converter



Additional Winding (1:1) Returns the Magnetising Energy to the Source

Switched Mode Power Conversion

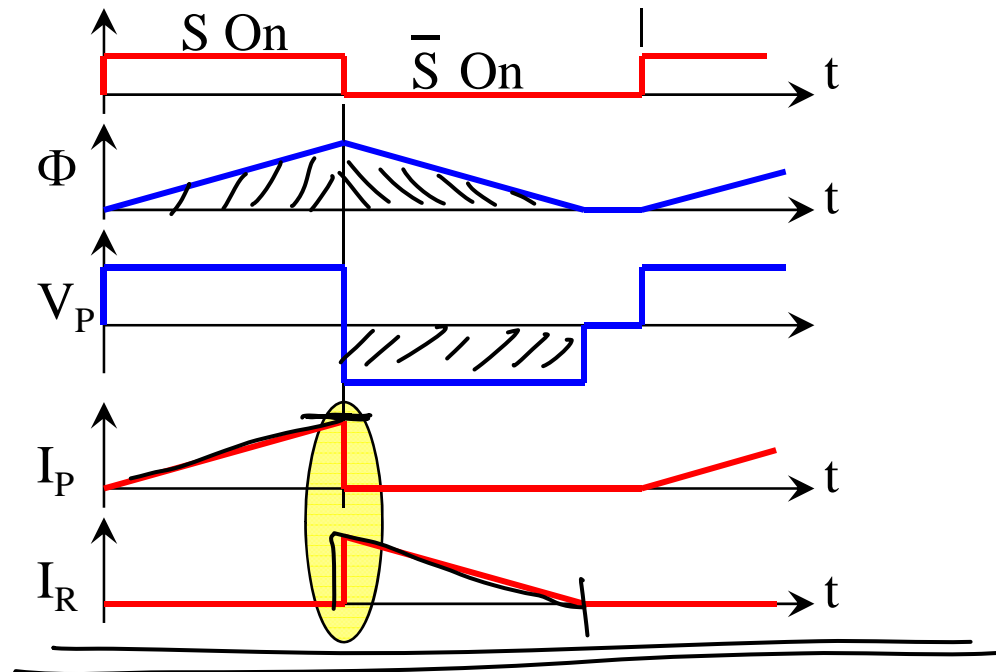
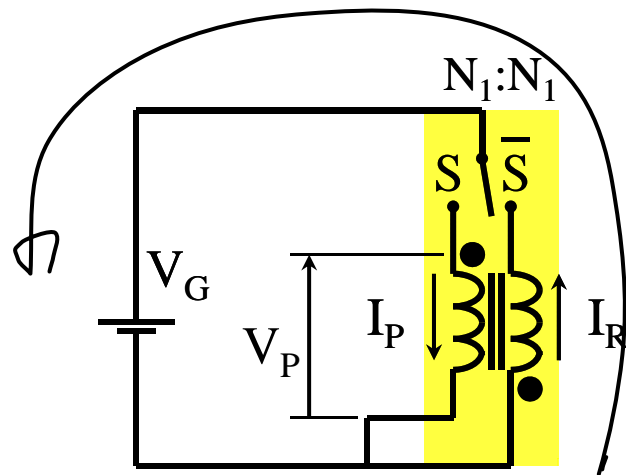
Concept Behind Lossless Reset



The Reset Winding (1:1) is Tightly Coupled
To Primary

Switched Mode Power Conversion

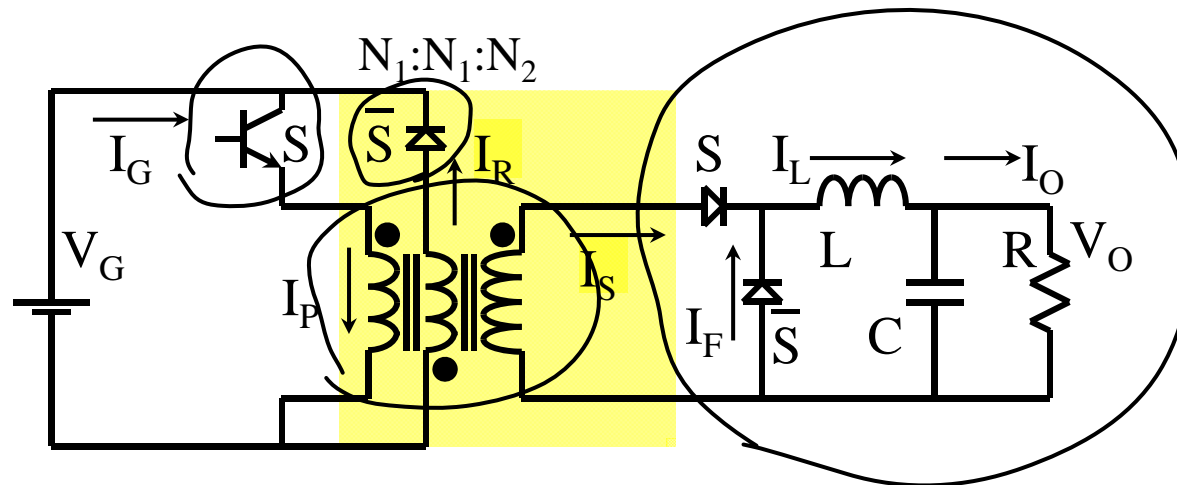
Concept Behind Lossless Reset



The Reset Winding (1:1) is Tightly Coupled To Primary

Switched Mode Power Conversion

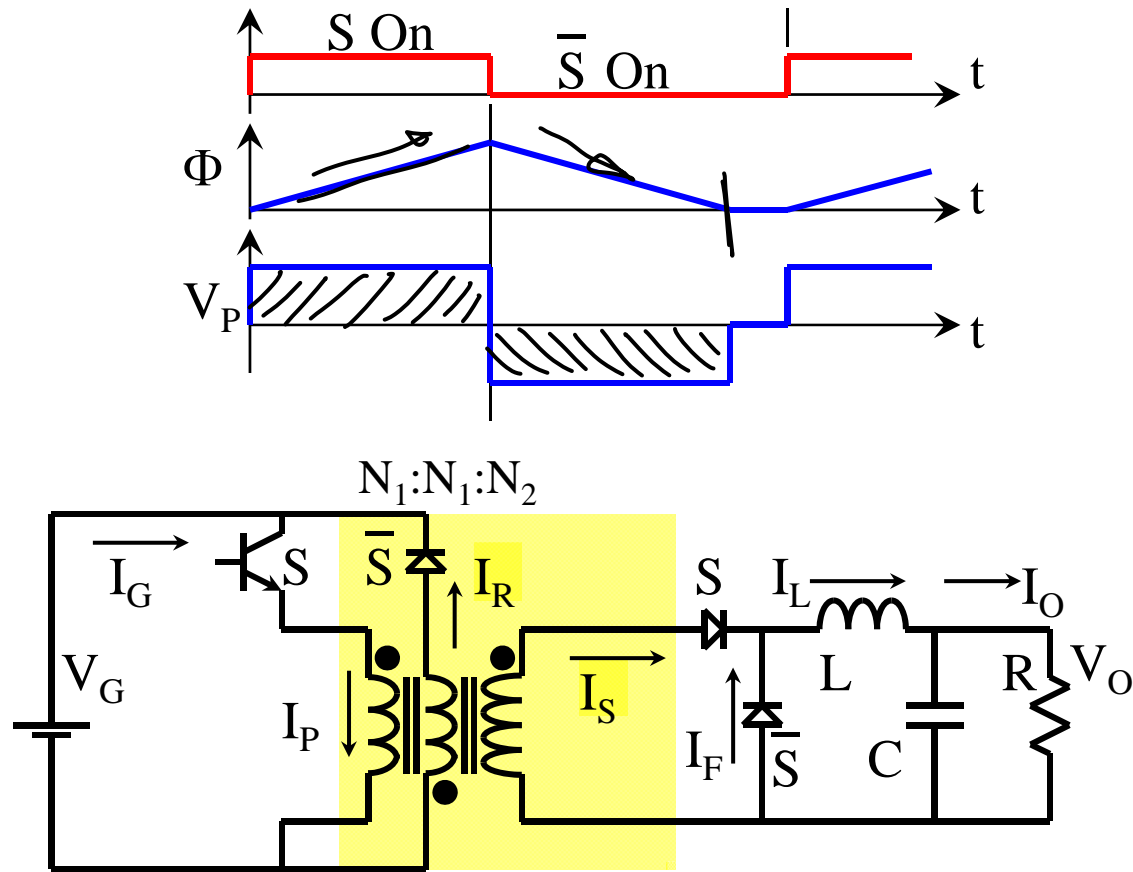
Lossless Forward Converter



Reset Winding is rated for Magnetising Current only
Primary & Reset Winding are Wound Bifilar

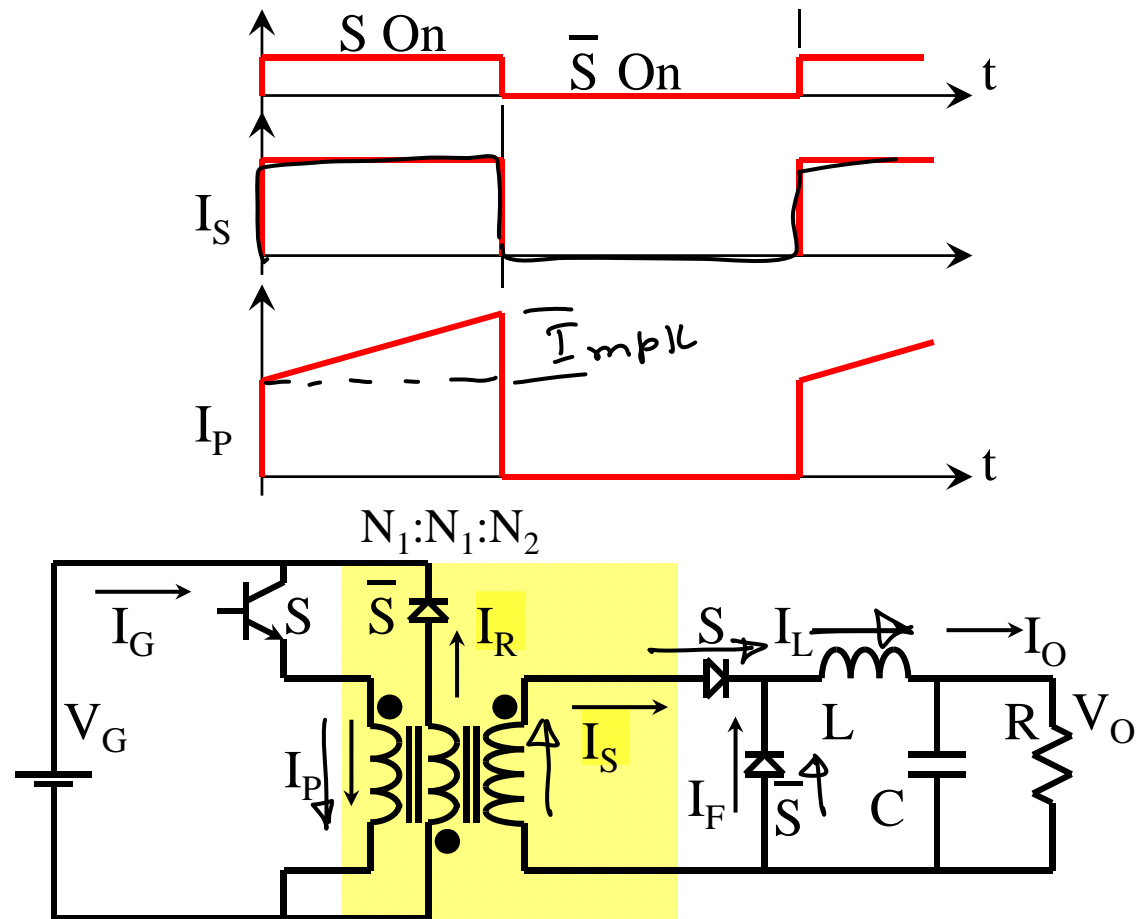
Circuit Realisation

Switched Mode Power Conversion



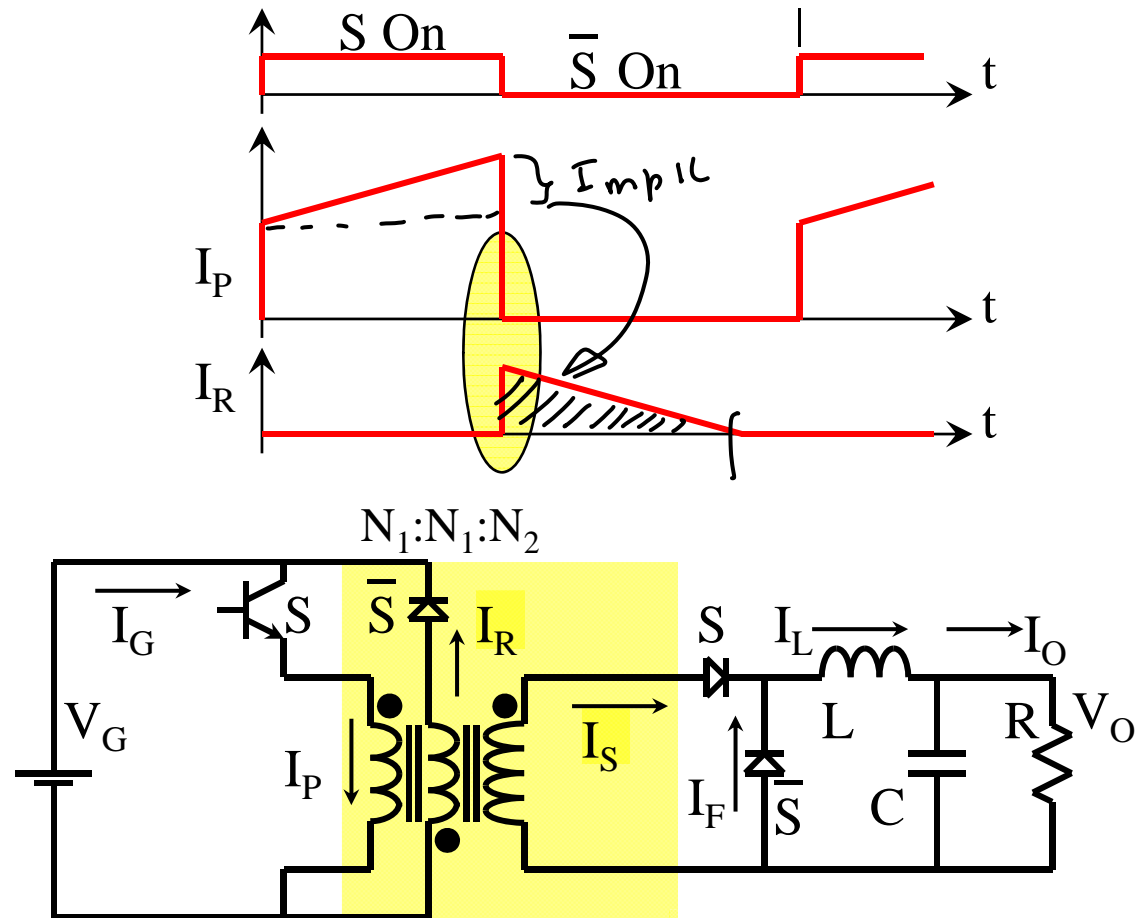
Flux & Reset Voltage

Switched Mode Power Conversion



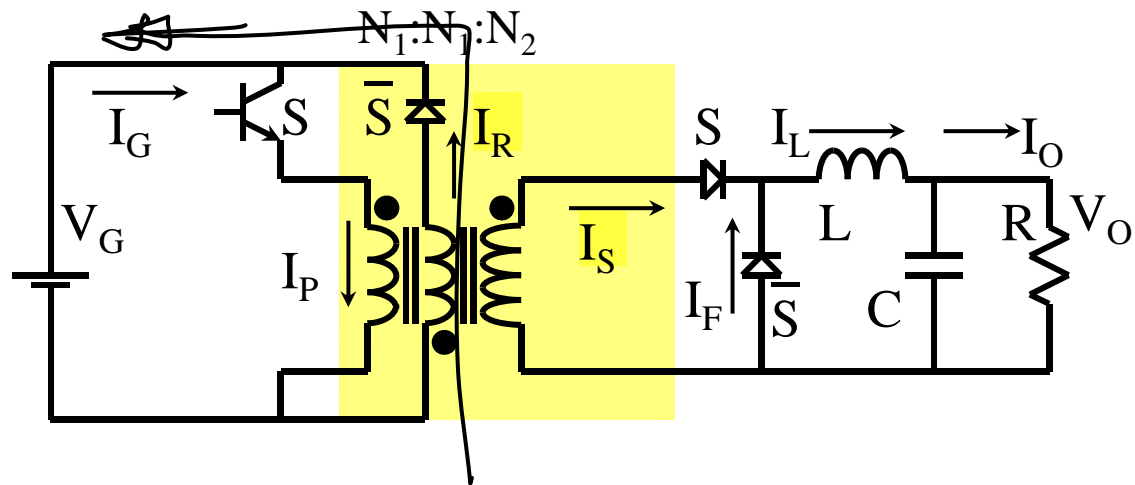
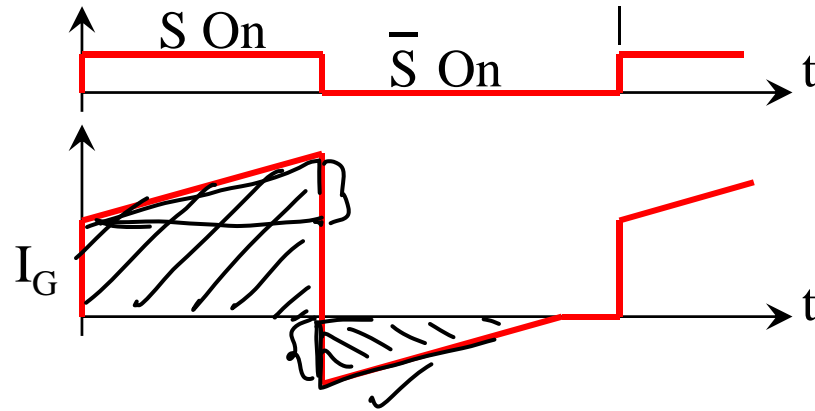
Secondary & Primary Current

Switched Mode Power Conversion



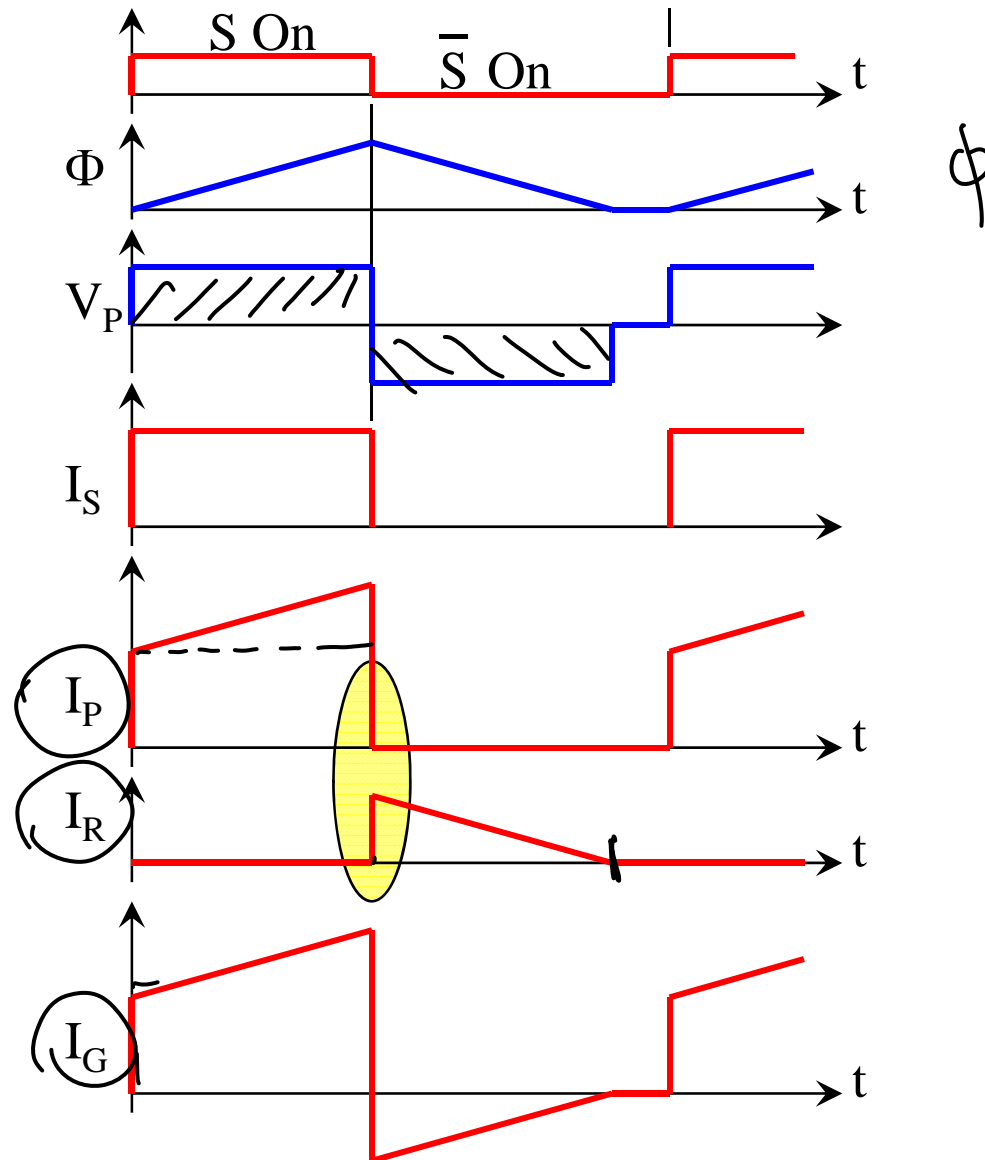
Primary & Reset Current

Switched Mode Power Conversion



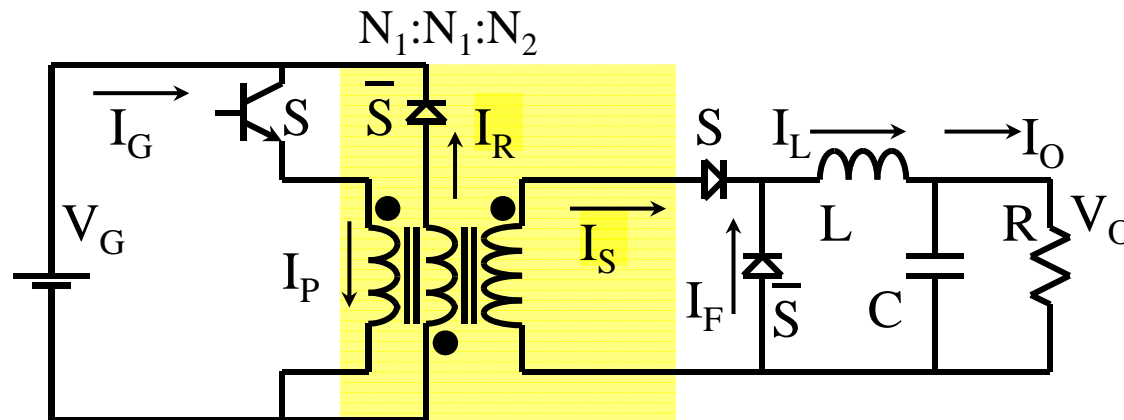
Source Current

Switched Mode Power Conversion



Switched Mode Power Conversion

Lossless Reset Forward Converter – Highlights



Isolation between V_O and V_G

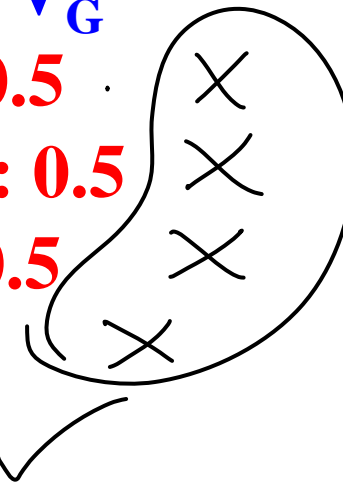
Maximum Duty Ratio: 0.5

Magnetic Core Utilisation: 0.5

Conductor Utilisation: 0.5

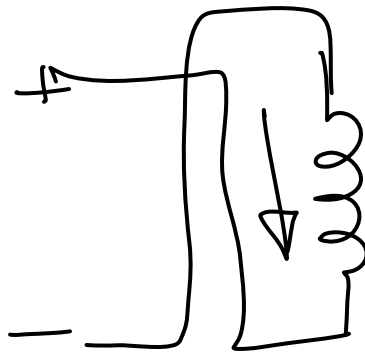
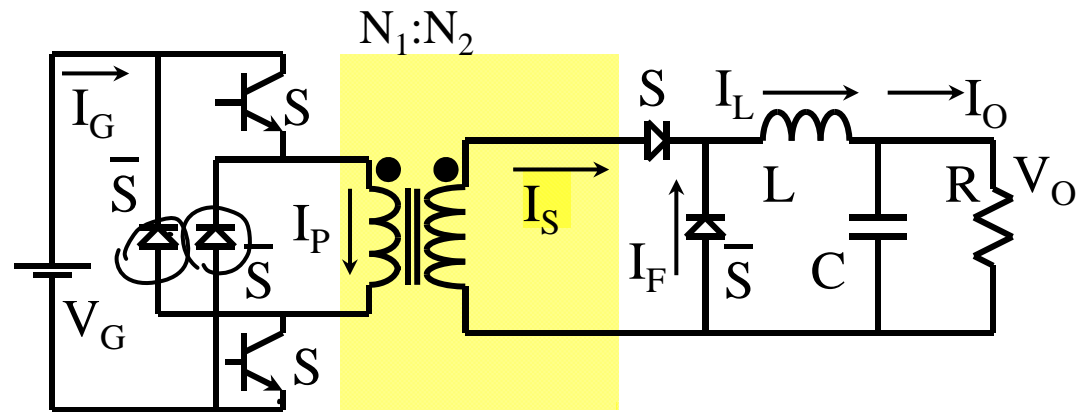
Circuit Voltage: 0.5

Lossless Reset



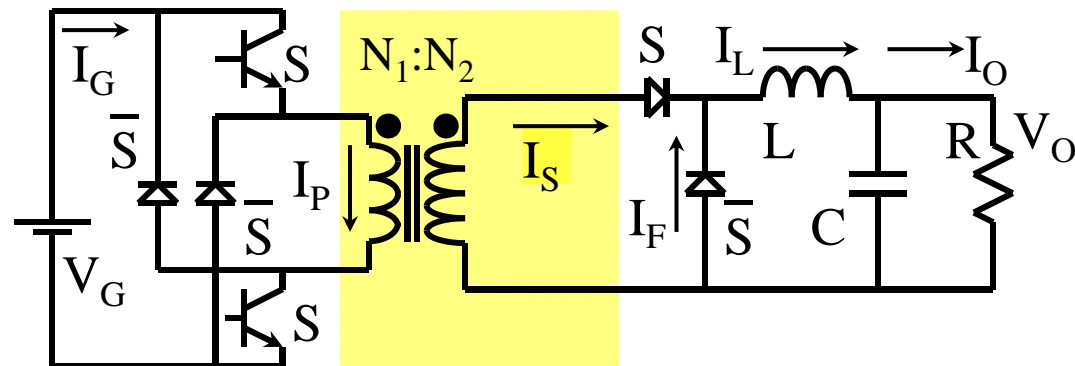
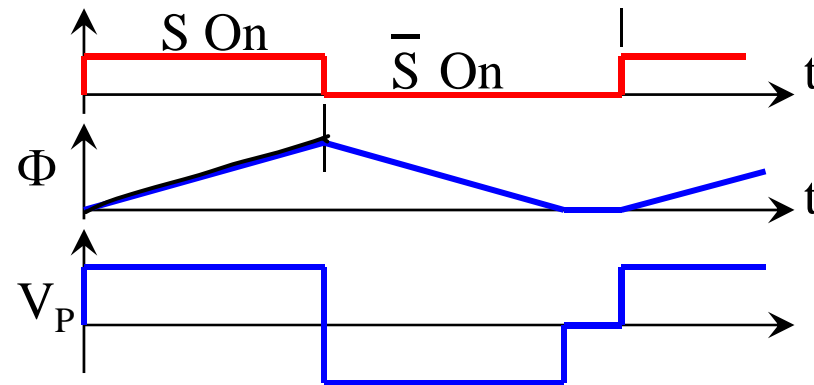
Switched Mode Power Conversion

Lossless Two Switch Forward Converter



Switched Mode Power Conversion

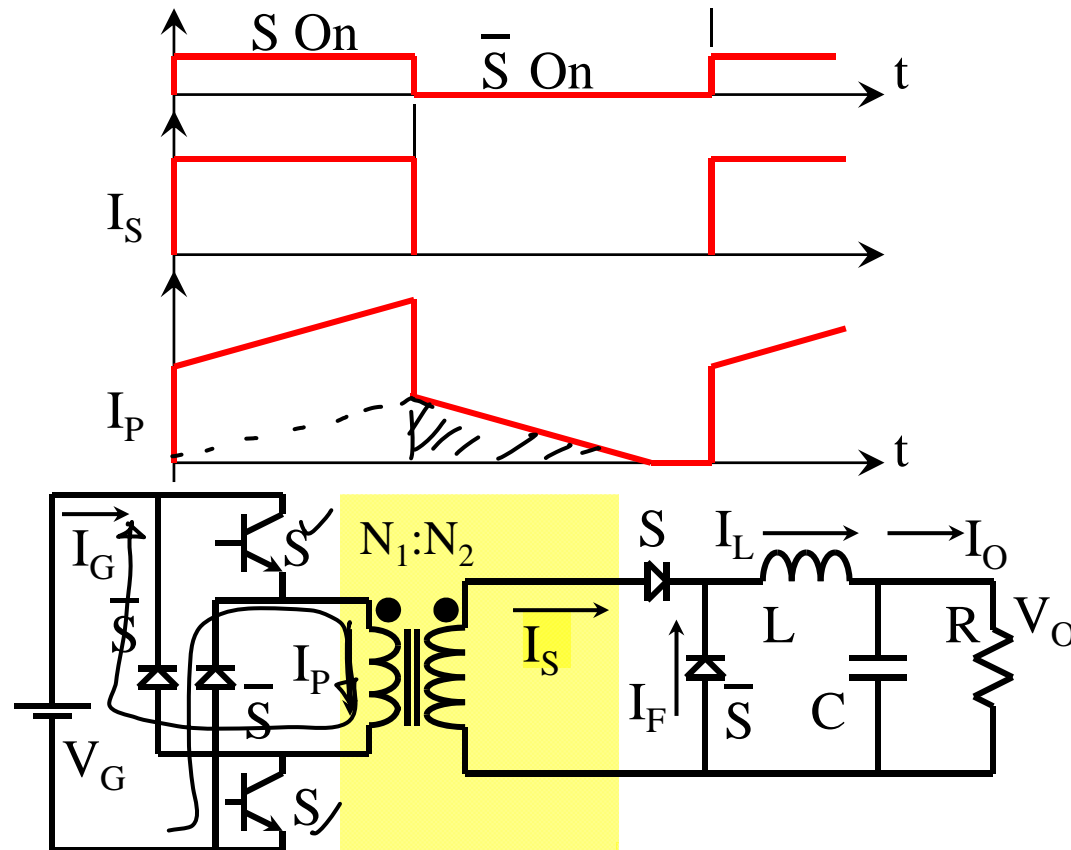
Lossless Two Switch Forward Converter



Core Flux & Primary Voltage

Switched Mode Power Conversion

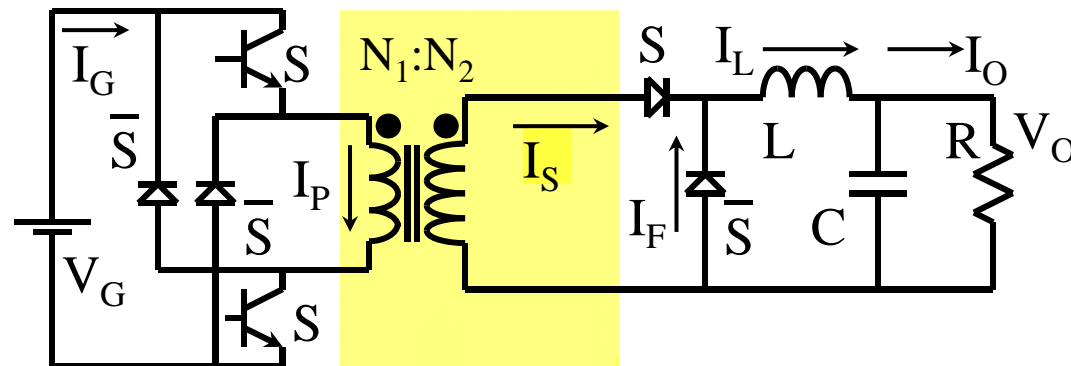
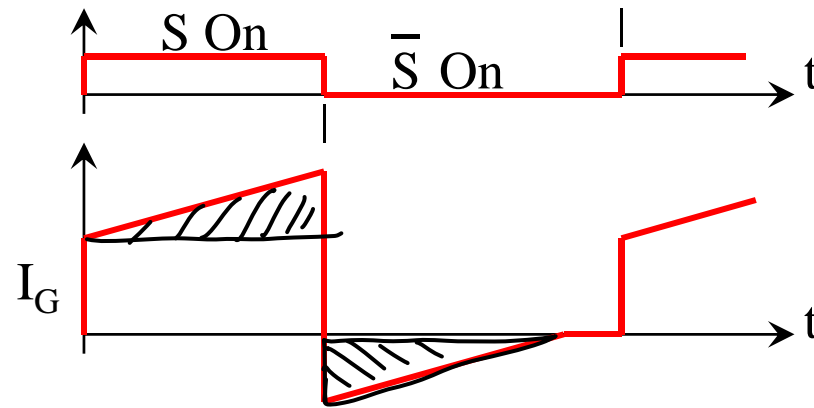
Lossless Two Switch Forward Converter



Secondary & Primary Current

Switched Mode Power Conversion

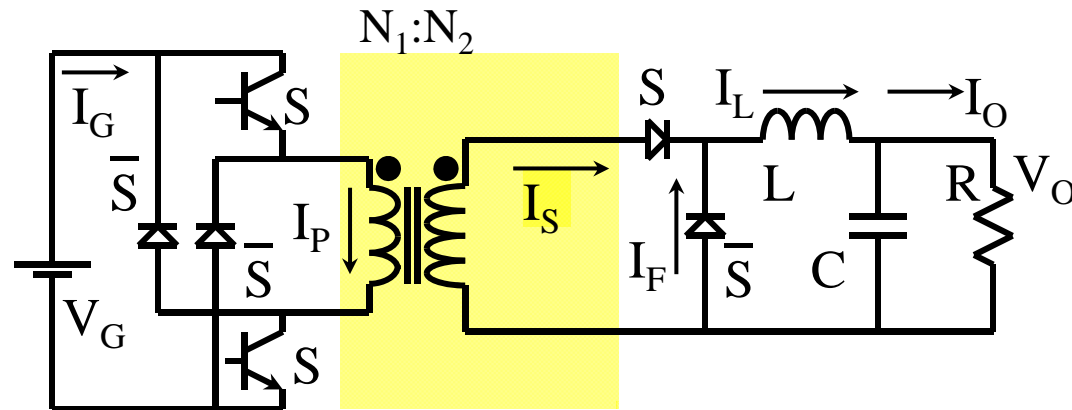
Lossless Two Switch Forward Converter



Source Current

Switched Mode Power Conversion

Lossless Two Switch Forward Converter – Highlights



Isolation between V_O and V_G ✓✓

Maximum Duty Ratio: 0.5 ✗

Magnetic Core Utilisation: 0.5 ✗

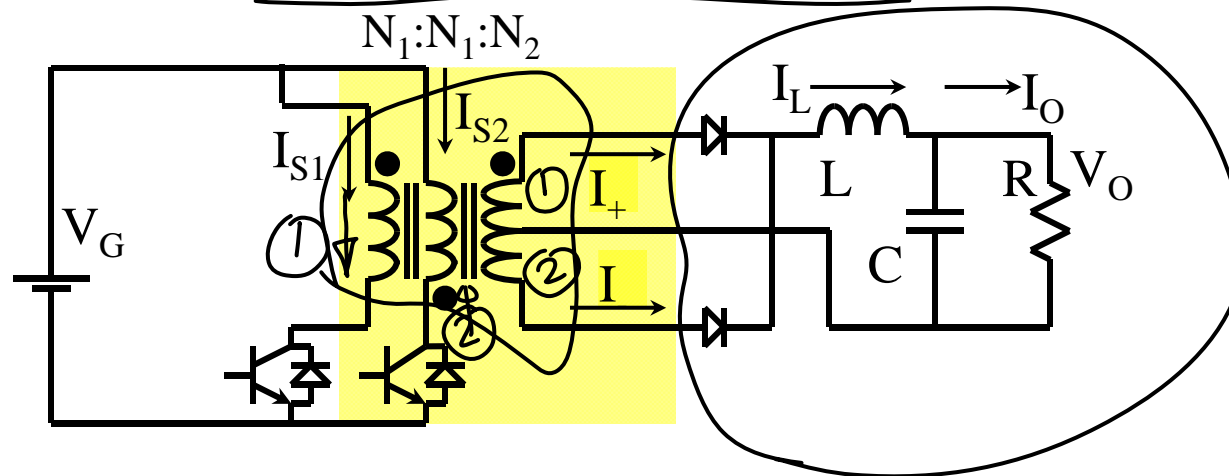
Conductor Utilisation: 0.5 ✗

Circuit Voltage: 1.0 ✓

Lossless Reset ✓

Switched Mode Power Conversion

Push-Pull Converter



Switches turn-on with PWM in alternate half cycles

Flux resetting is done in Complementary Fashion

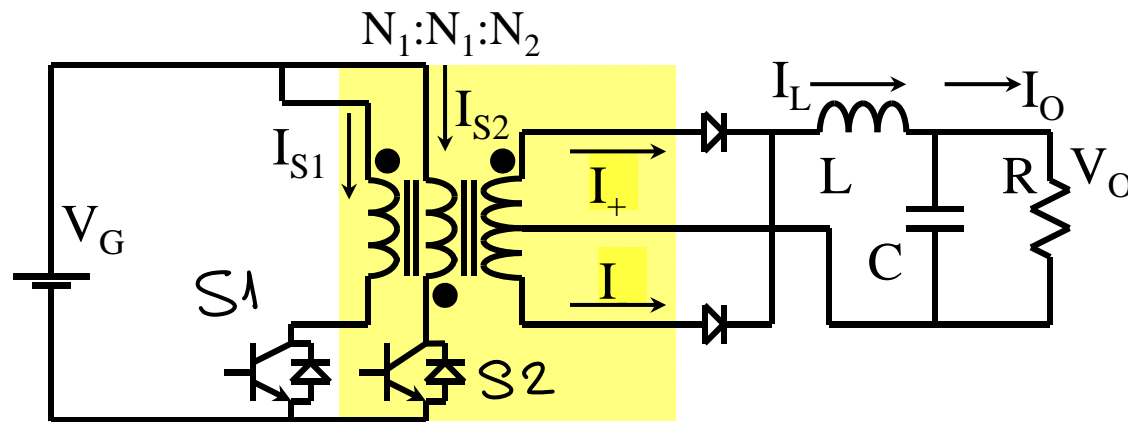
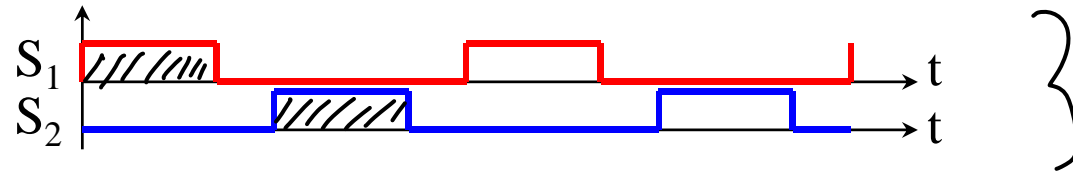
Duty ratio of primary switches $< 50\%$

Secondary duty ratio $< 100\%$ ✓

Back-to-Back Forward Converters

Switched Mode Power Conversion

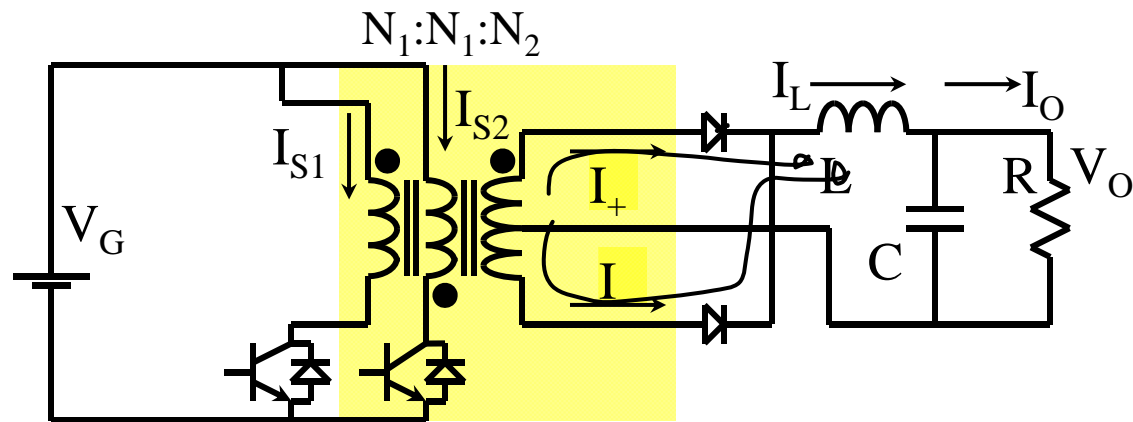
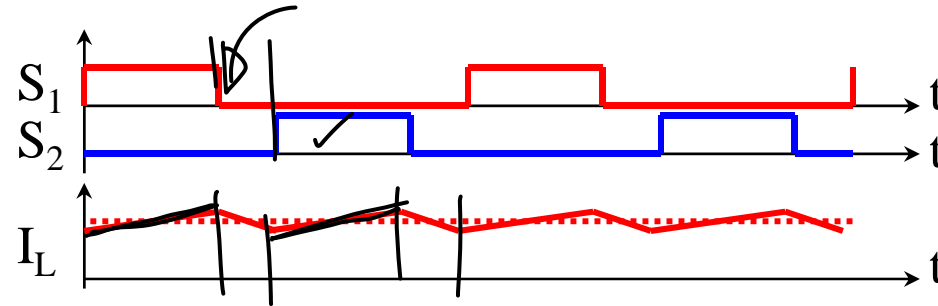
Push-Pull Converter – Waveforms



Switch On State Intervals

Switched Mode Power Conversion

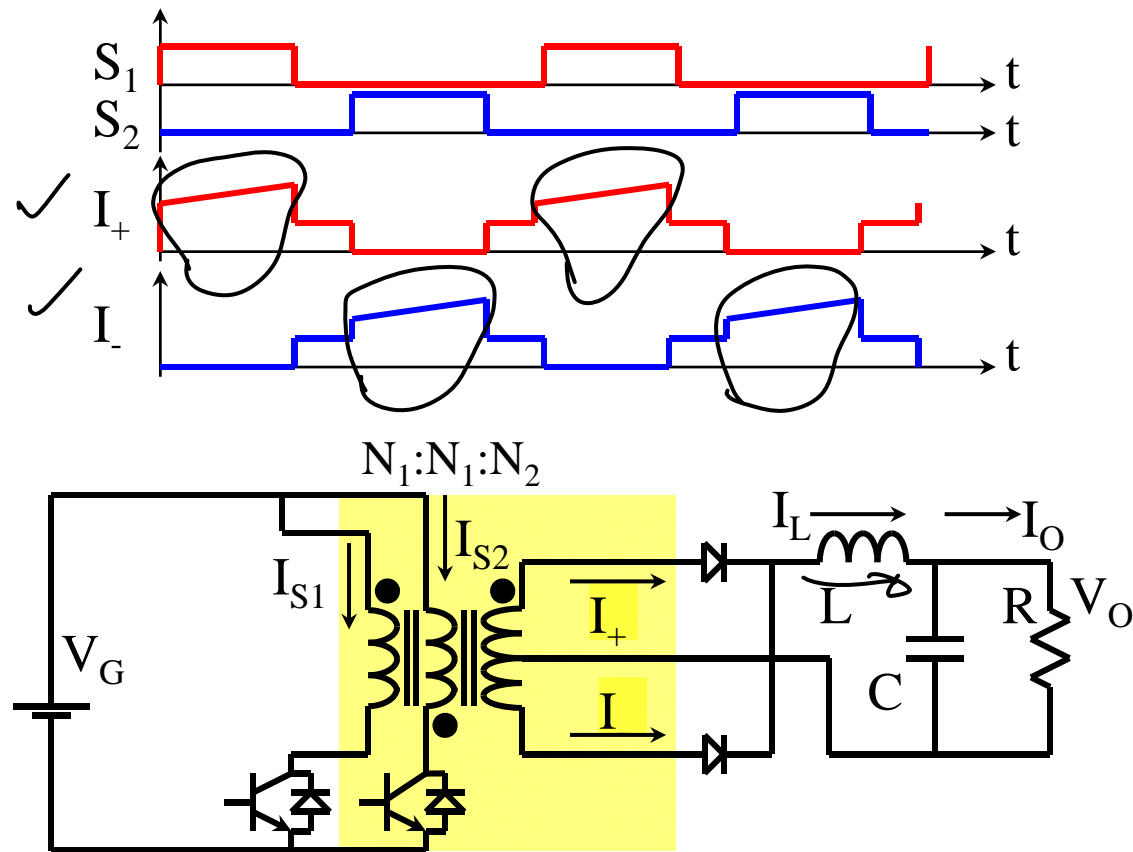
Push-Pull Converter – Waveforms



Output Inductor Current

Switched Mode Power Conversion

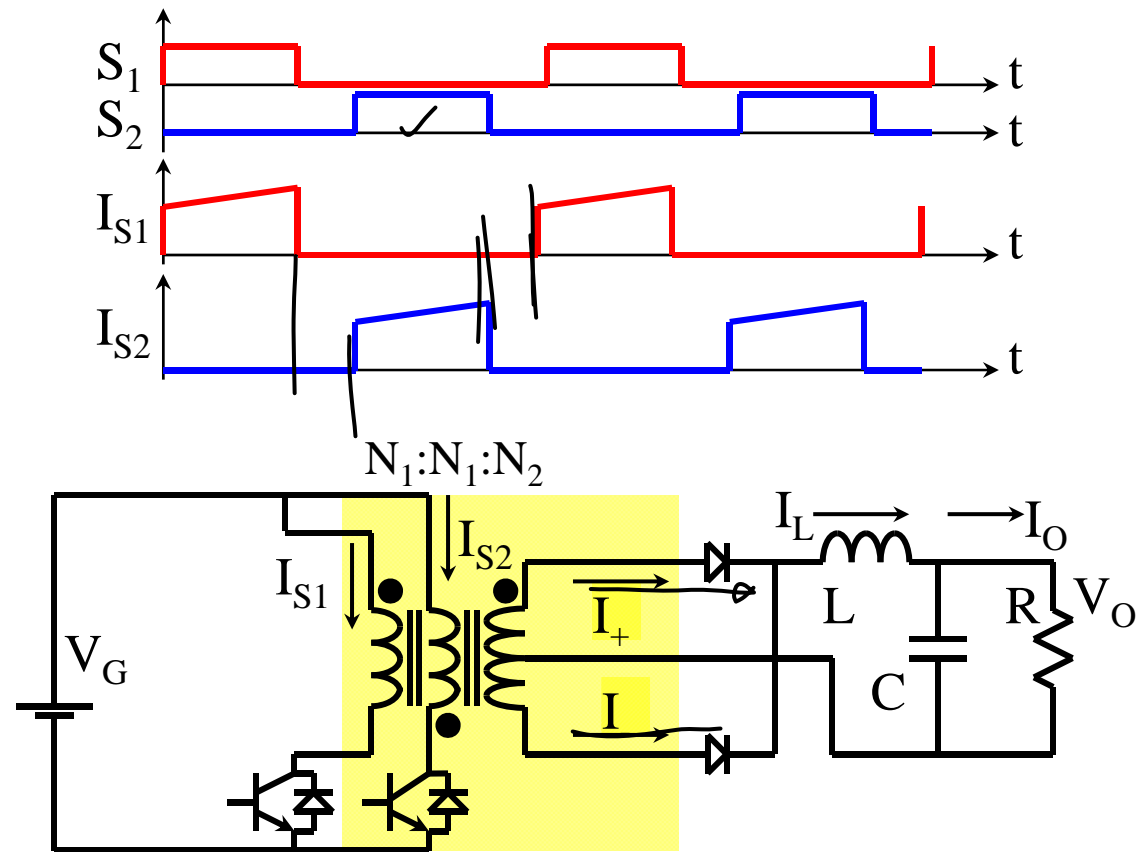
Push-Pull Converter – Waveforms



Secondary Currents

Switched Mode Power Conversion

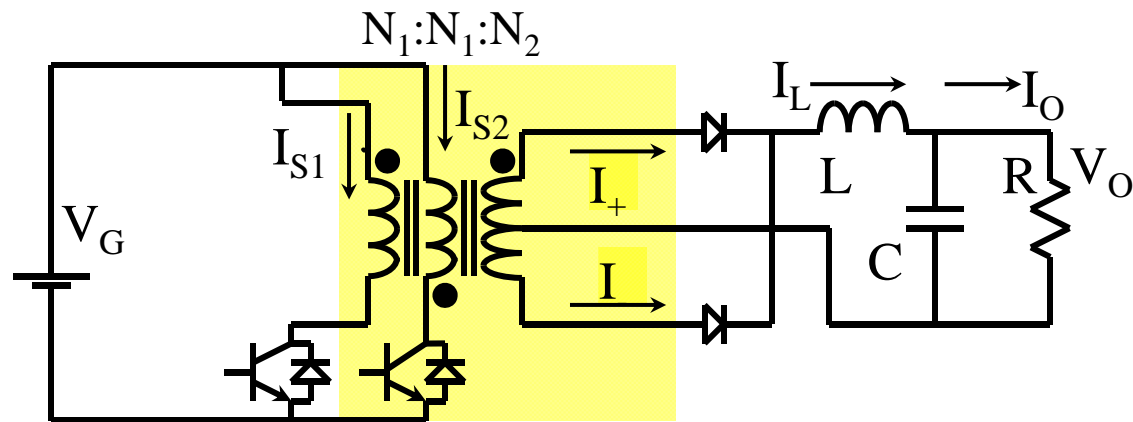
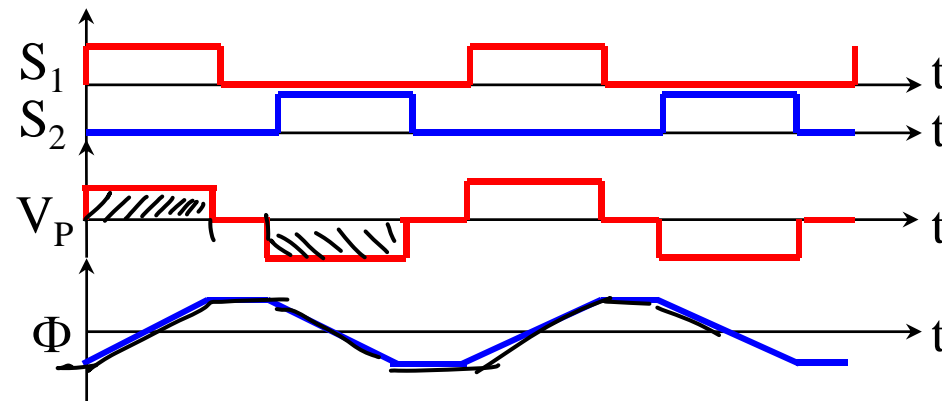
Push-Pull Converter – Waveforms



Switch Currents

Switched Mode Power Conversion

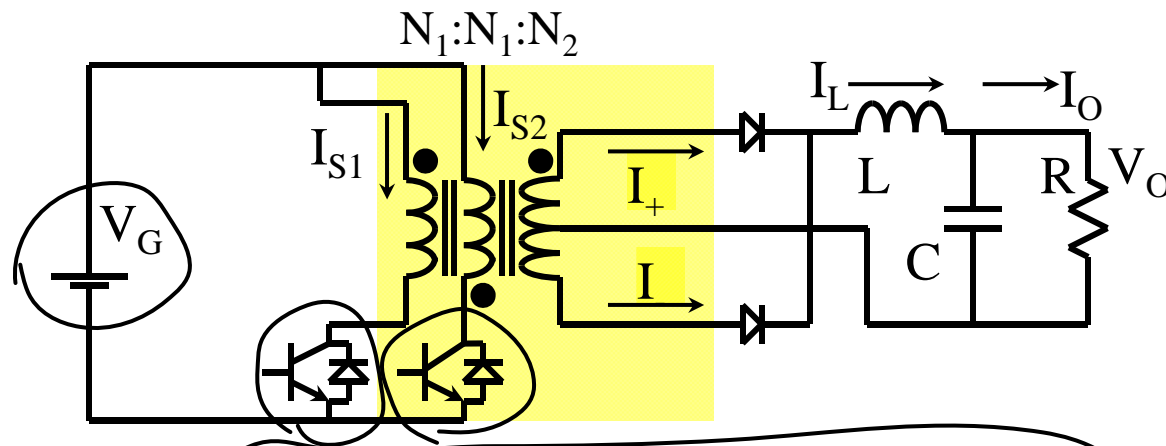
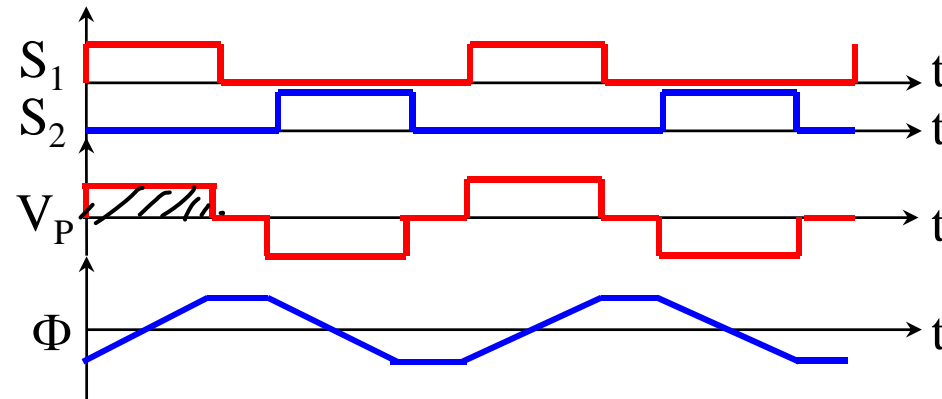
Push-Pull Converter – Waveforms



Transformer Primary Voltage & Flux

Switched Mode Power Conversion

Push-Pull Converter – Waveforms

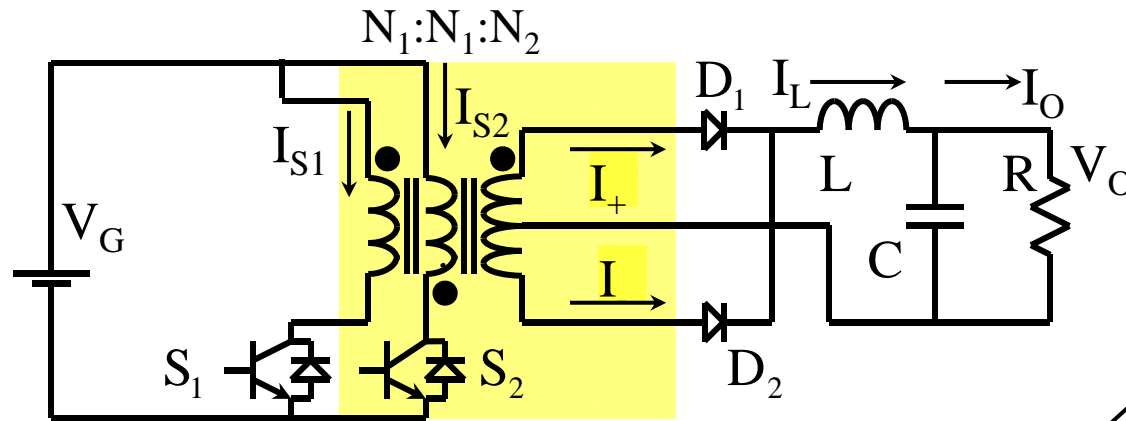


$\tau_{on} +$
 $\tau_{zn} -$

Hazard of Core Saturation

Switched Mode Power Conversion

Push-Pull Converter – Highlights



Isolation between V_O and V_G ✓

Maximum Duty Ratio: 1.0 ✓

Magnetic Core Utilisation: 1.0 ✓

Conductor Utilisation: 0.5

Circuit Voltage: 0.5

Lossless Reset ✓

Hazard of Core saturation

Low powers

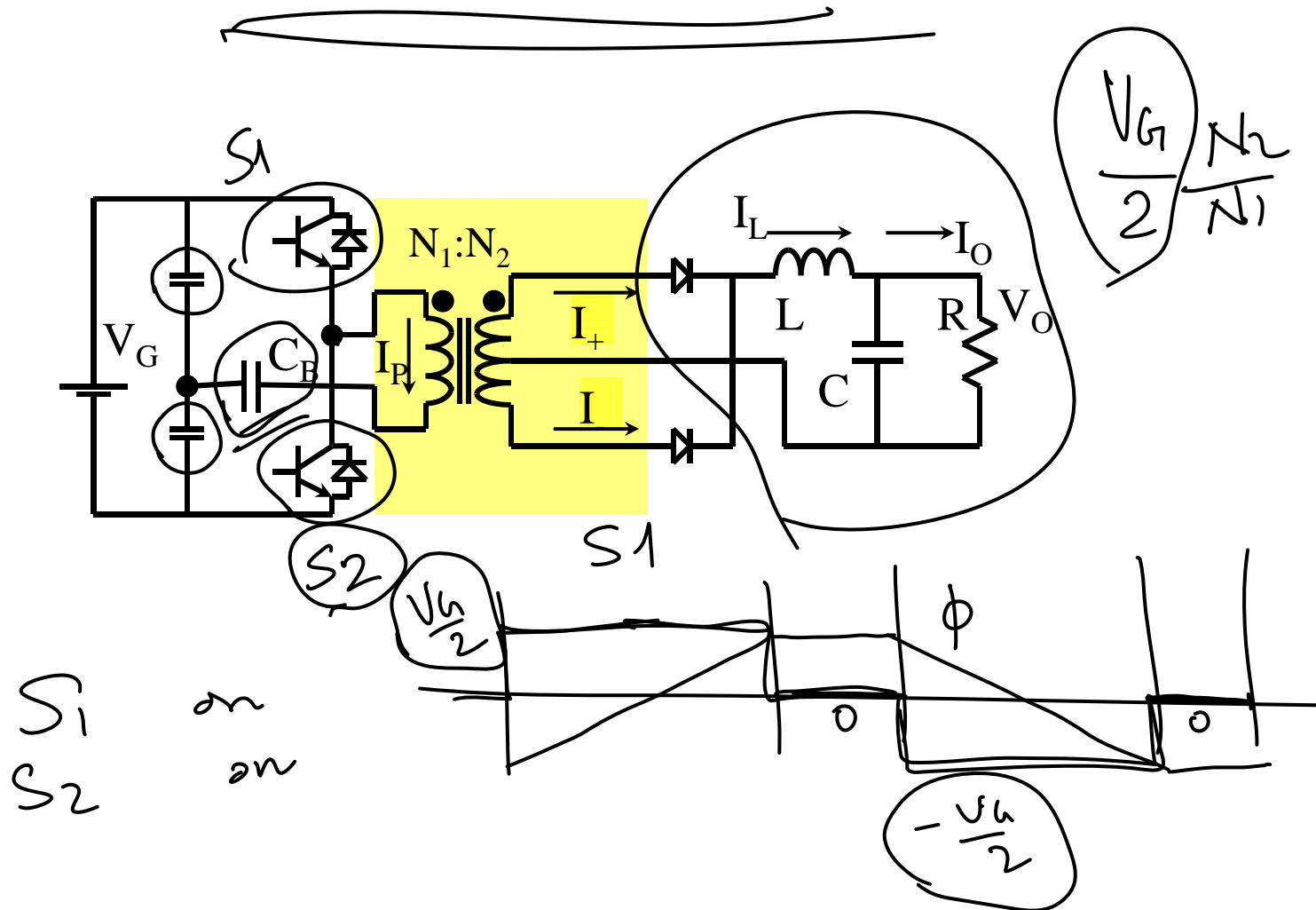
Switched Mode Power Conversion

Other Isolated Converters

Half Bridge Converter	✓	MEDIUM
Full Bridge Converter	✓	BIG
Isolated Flyback Converter	✓	SMALL

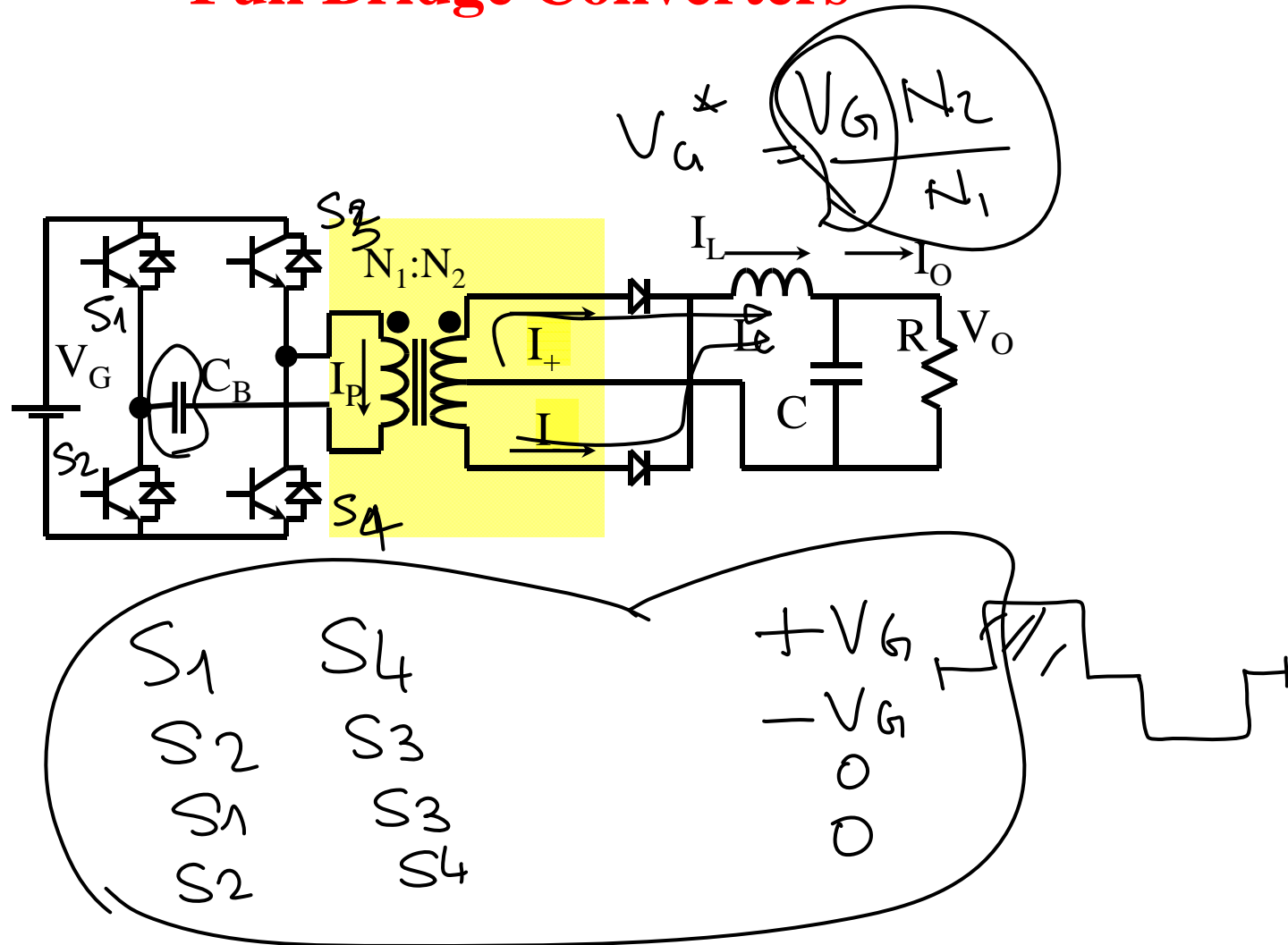
Switched Mode Power Conversion

Half Bridge Converters



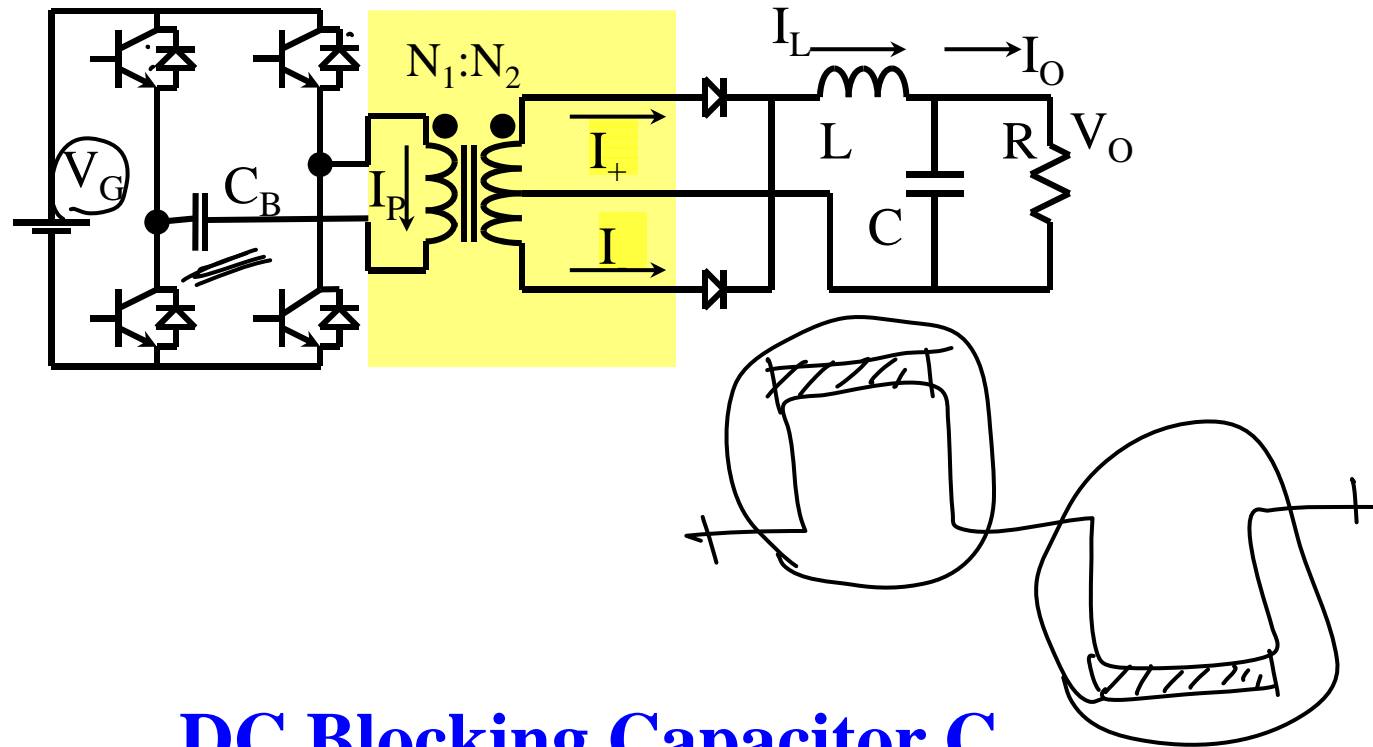
Switched Mode Power Conversion

Full Bridge Converters



Switched Mode Power Conversion

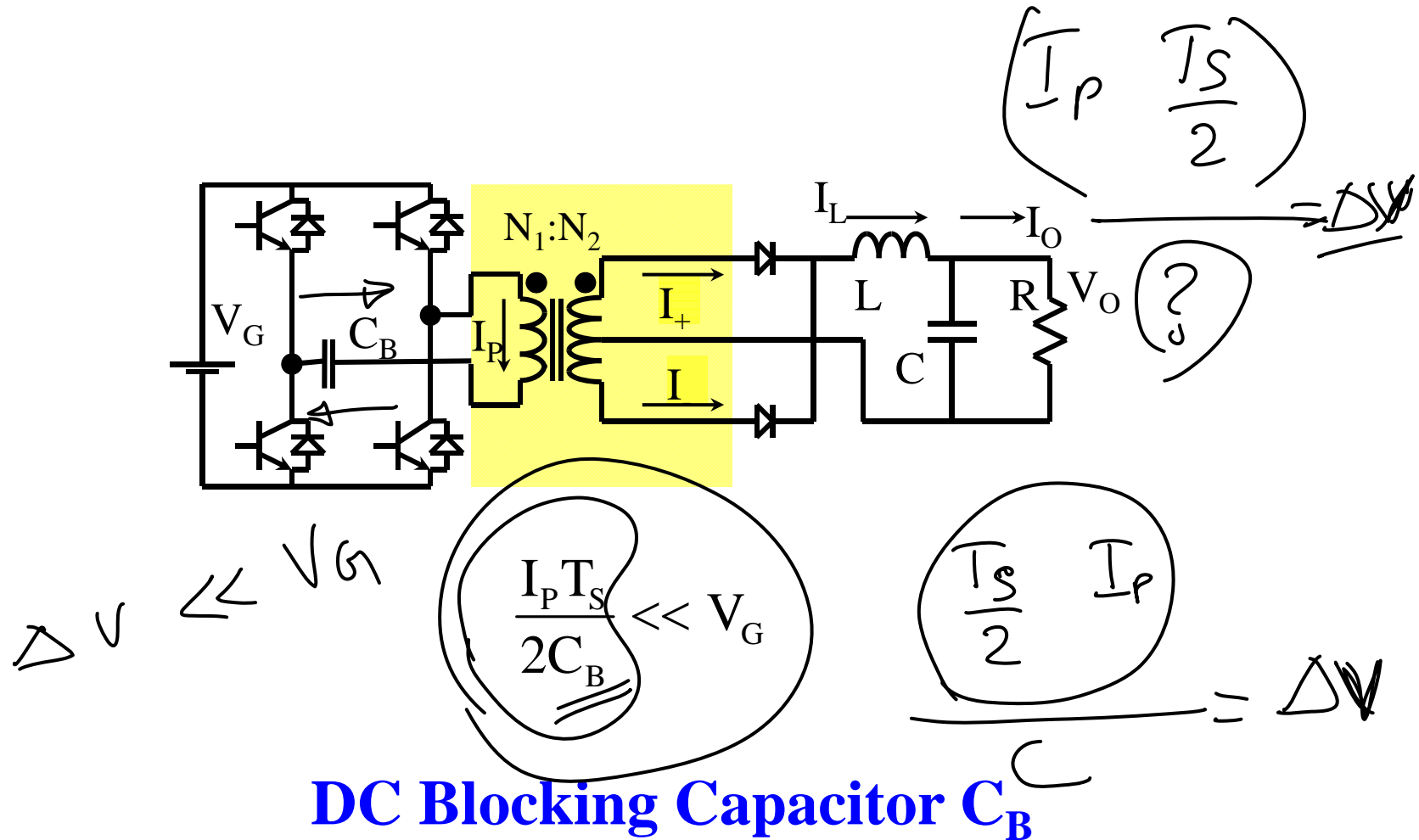
Full Bridge Converters



DC Blocking Capacitor C_B

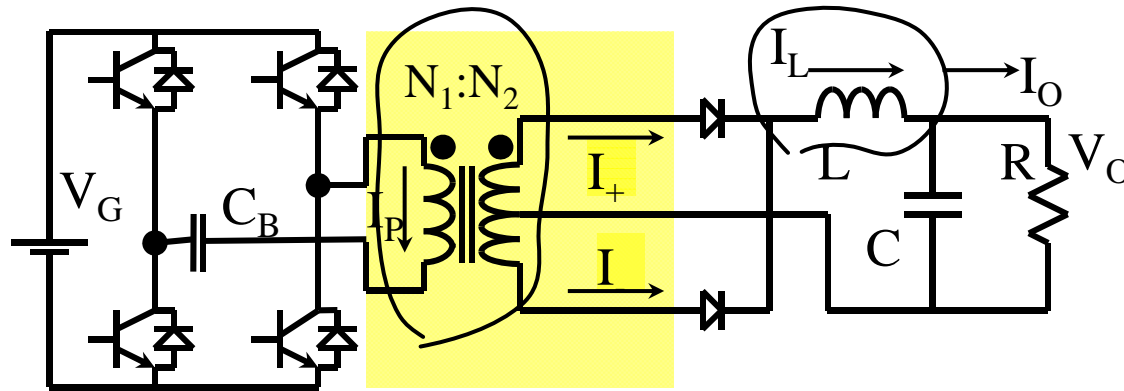
Switched Mode Power Conversion

Full Bridge Converters



Switched Mode Power Conversion

Full Bridge Converters



Isolation between V_O and V_G ✓

Maximum Duty Ratio: 1.0 ✓

Magnetic Core Utilisation: 1.0 ✓

Conductor Utilisation: 1.0 ✓

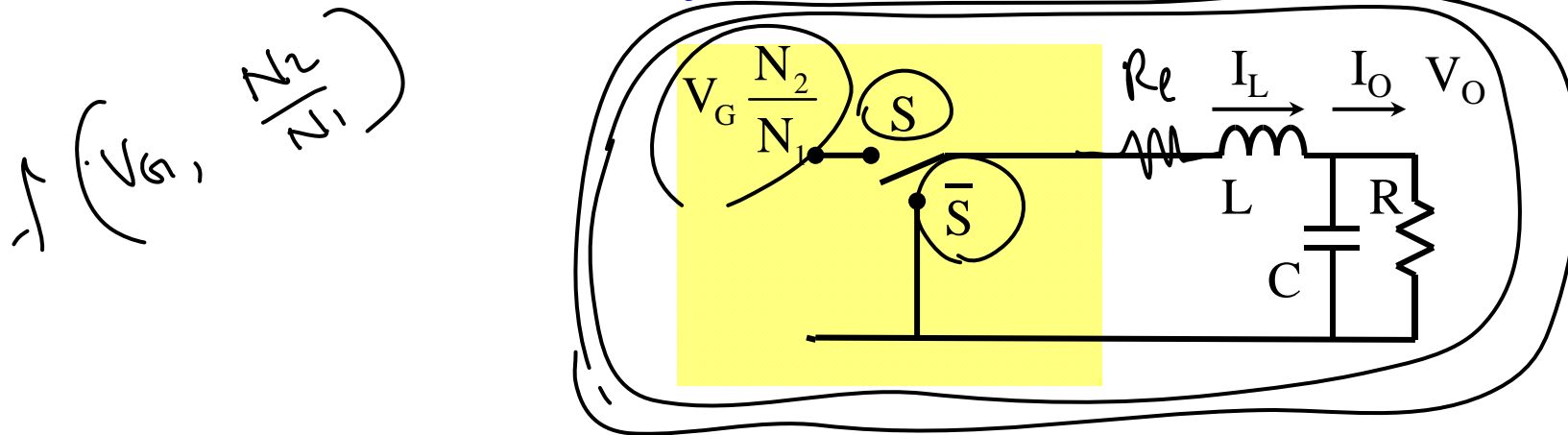
Circuit Voltage: 0.5/1.0 ✓

Switched Mode Power Conversion

Forward Converter – Non-isolated Equivalent Circuit

Idealised Analysis can be done on the Non-isolated
Equivalent Circuit

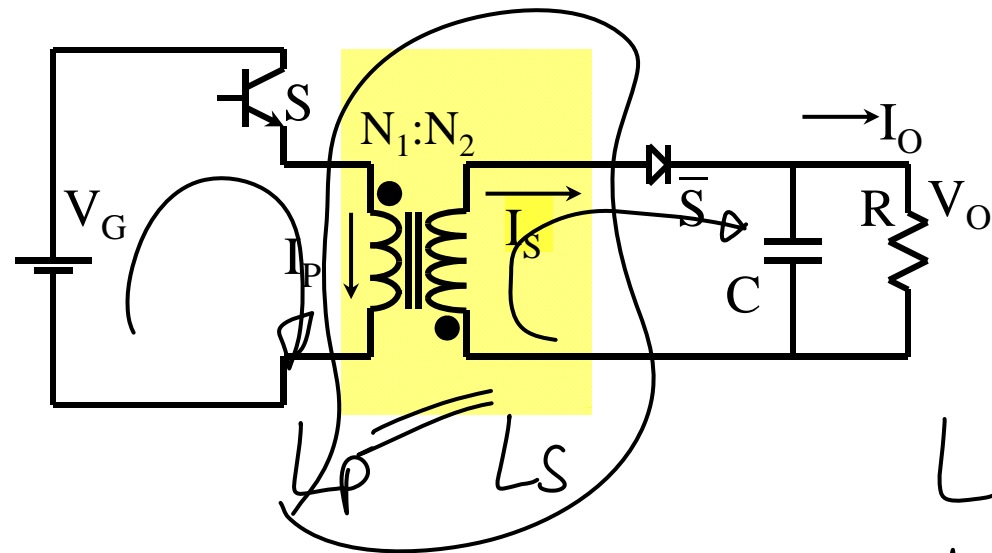
Effect of Switch, Inductor, Source Non-idealities
May also be Evaluated



Non-Isolated Equivalent Circuit

Switched Mode Power Conversion

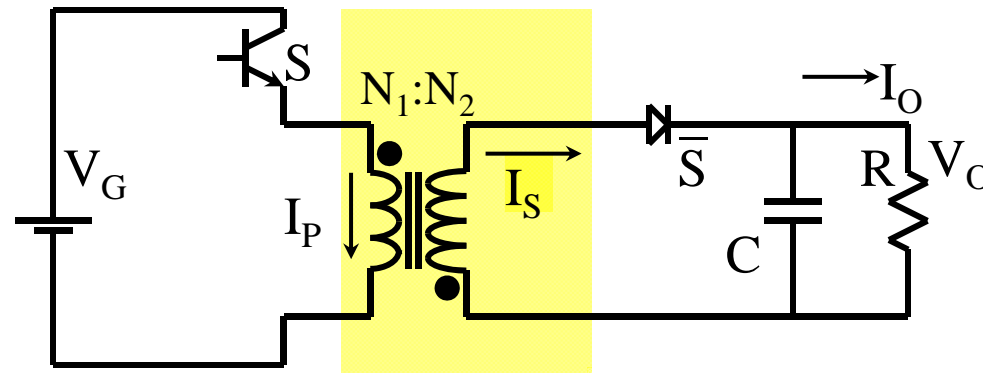
Isolated Flyback Converters



$$L_p \propto N_p^2$$
$$L_s \propto N_s^2$$

Switched Mode Power Conversion

Isolated Flyback Converters - Features



Isolation between V_O and V_G

Maximum Duty Ratio: $2/3$

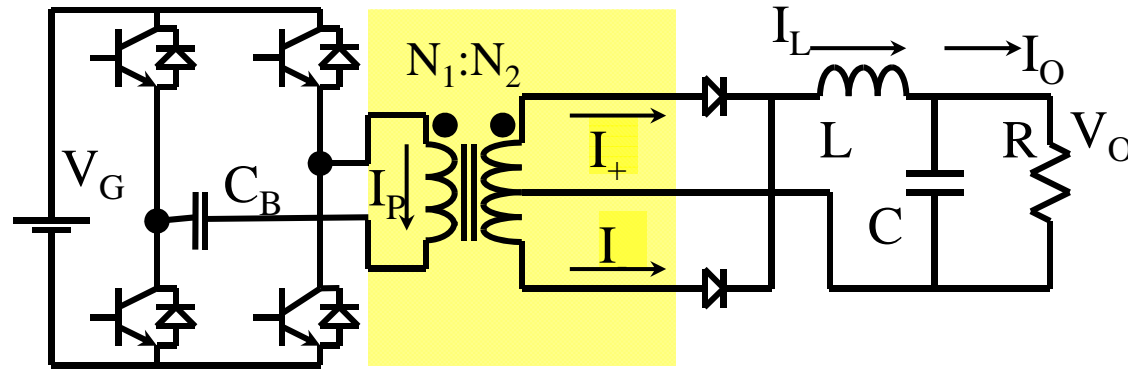
Magnetic Core Utilisation: 0.5

Conductor Utilisation: 0.5

Circuit Voltage: 0.5

Switched Mode Power Conversion

Half/Full Bridge Converters



Isolation between V_O and V_G

Maximum Duty Ratio: 1.0

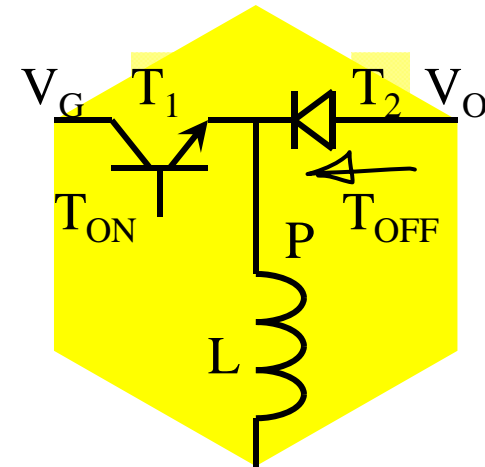
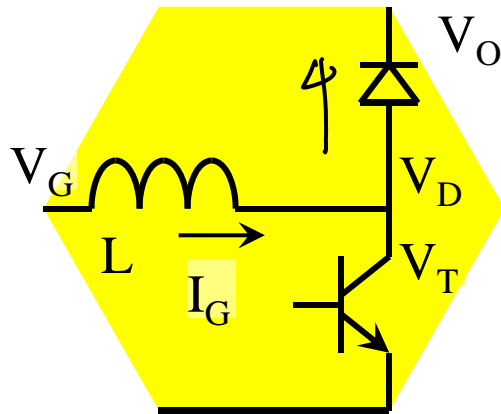
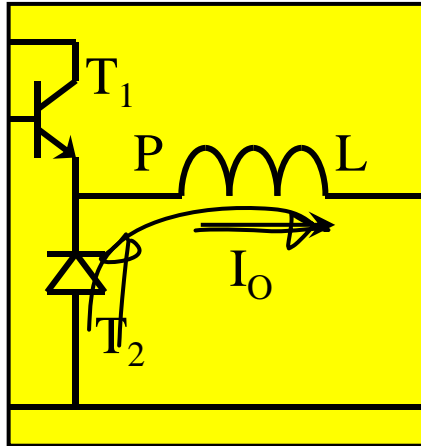
Magnetic Core Utilisation: 1.0

Conductor Utilisation: 1.0

Circuit Voltage: 0.5/1.0

Switched Mode Power Conversion

Converters in Canonical Form



Switched Mode Power Conversion

Operating Modes – CCM and DCM

