

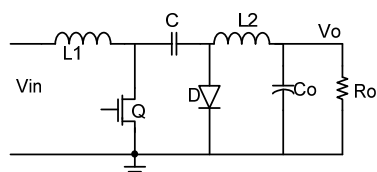


Advanced topologies Half-bridge, Full-bridge, Push-Pull, C'uk, SEPIC

- C'uk
- Sepic
- Half-bridge
 - Symmetrical operation
 - Double power supply
 - Principle of operation , definition of D
 - Using bus capacitors – capacitive voltage division?
 - The concept of split bus capacitor
 - Component stress
 - Asymmetrical operation
- Full-bridge
 - Operation
 - Stress
- Reset
- Push-pull

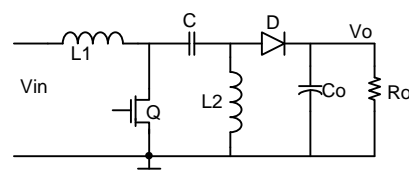


Types of PWM converters C'uk and SEPIC



C'uk

$$\frac{V_o}{V_{in}} = -\frac{D}{1-D}$$

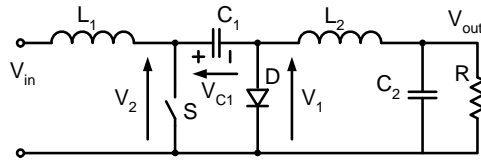


SEPIC

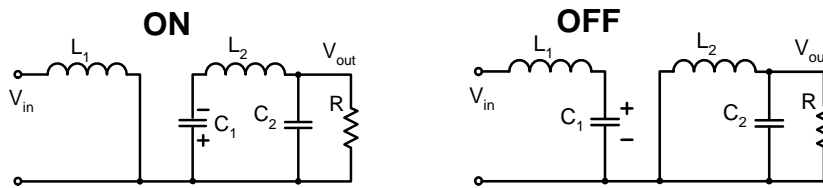
$$\frac{V_o}{V_{in}} = \frac{D}{1-D}$$



C'uk Converter



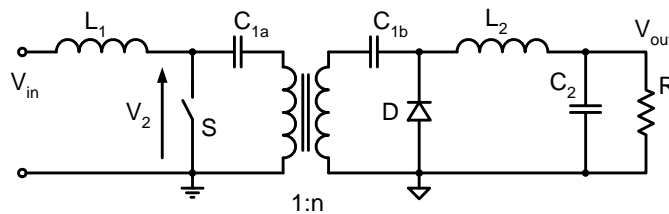
Voltage of $C_1 \approx$ constant



$$\begin{aligned} \bar{V}_1 &= V_o & V_o &= -V_{c1} \cdot D_{on} \text{ (buck)} \\ \bar{V}_2 &= V_{in} & V_o &= -(V_{in} - V_o) \cdot D_{on} \\ \bar{V}_{c1} &= V_{in} - V_o & \frac{V_o}{V_{in}} &= -\frac{D_{on}}{D_{off}} \end{aligned}$$



C'uk with isolation

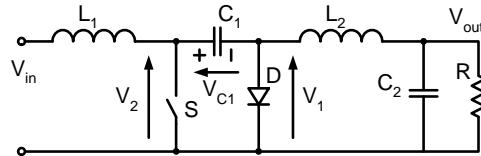


- Any polarity
- Any voltage ratio

$$\frac{V_o}{V_{in}} = \pm \frac{D_{on}}{D_{off}} n$$



C'uk Converter Inductors on the same core



Can be done only if the voltage on the windings are equal



C'uk advantages and disadvantages

Advantages

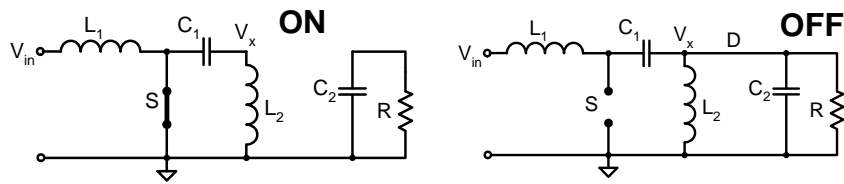
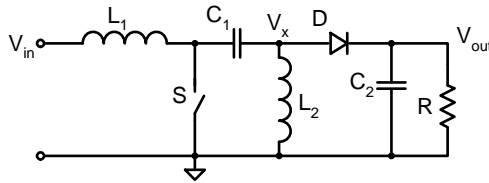
- Continues input **and** output currents
- Single switch
- Step-up and step-down

Disadvantages

- Two inductors
- Extra capacitor (of high rms current)
- Difficult to stabilize
- High voltage on switch $|V_{in}| + |V_{out}|$



SEPIC Converter



$$\bar{V}_{L1} = 0$$

$$\bar{V}_{L2} = 0$$

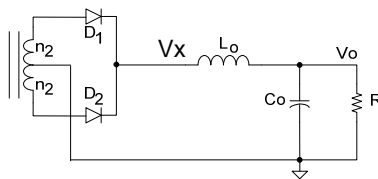
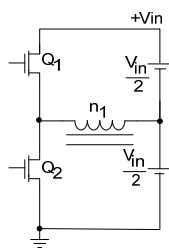
$$\bar{V}_{C1} = V_{in}$$

$$\bar{V}_x = V_o \cdot D_{off} - V_{in} \cdot D_{on} = 0$$

$$\frac{V_o}{V_{in}} = \frac{D_{on}}{D_{off}}$$



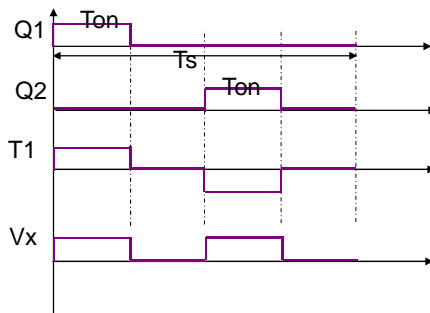
Half-bridge



HB,
symmetrical operation

$$\frac{V_o}{V_{in}} = \frac{n1}{n2} D$$

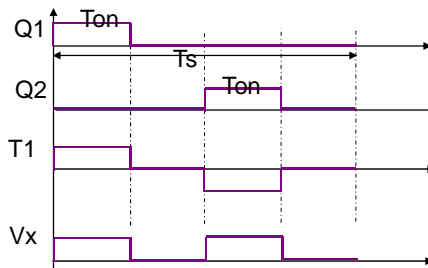
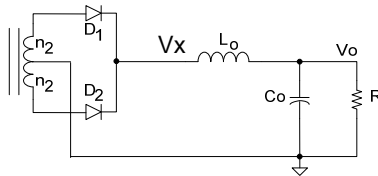
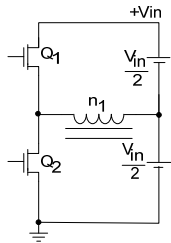
$$D = \frac{t_{on}}{T_s/2}$$



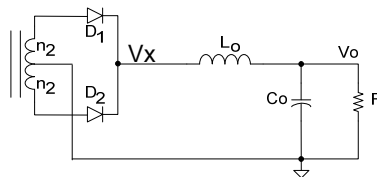
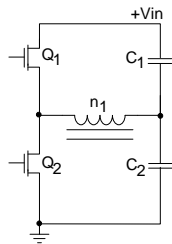


Half-bridge

What is the transformer voltage at off time



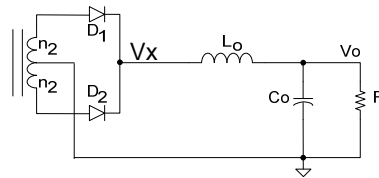
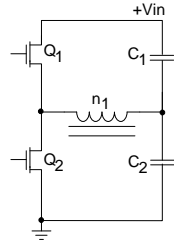
Types of PWM converters HB –Capacitors to replace supplies





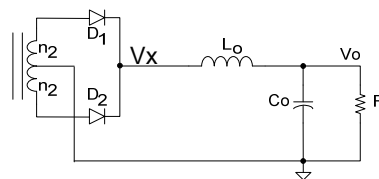
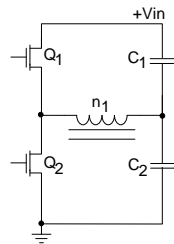
Types of PWM converters

HB - Concept of split bus capacitors



Types of PWM converters

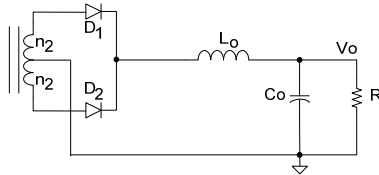
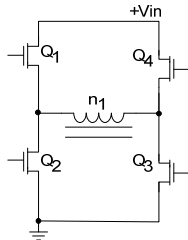
Asymmetrical operation – synchronous rectifier



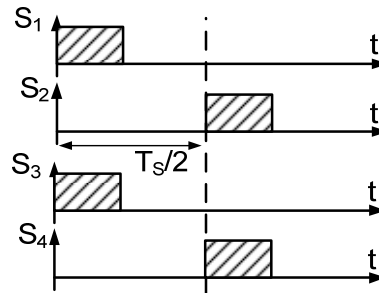
Motivation to asymmetrical operation: Spikes and oscillations at the mid point an off time



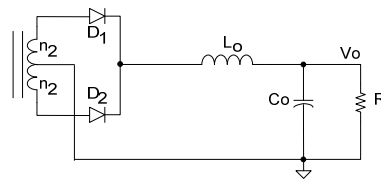
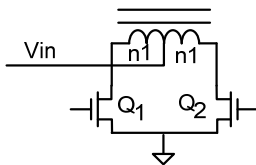
Full-bridge



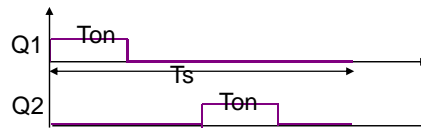
$$\frac{V_o}{V_{in}} = 2 \frac{n1}{n2} D$$



Push-pull



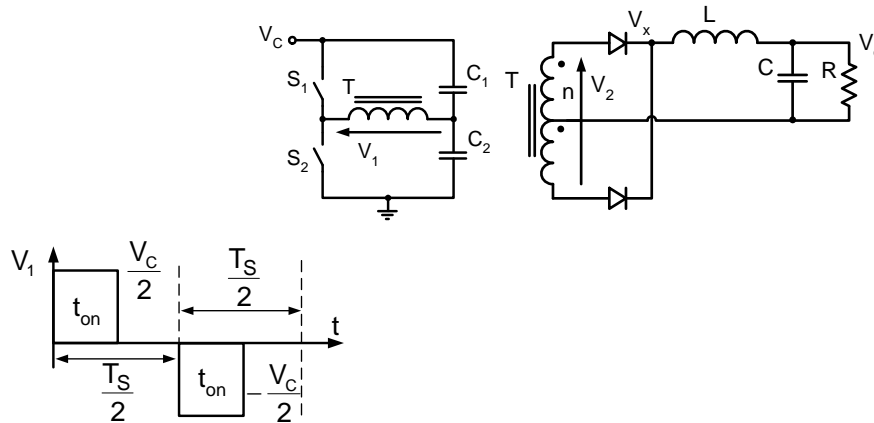
$$\frac{V_o}{V_{in}} = 2 \frac{n1}{n2} D$$





Reset of Forward, HB, FB

- Forward - auxiliary winding
- HB,FB - Natural



Forward, HB, FB, PP

I_L ripple for same L

- Forward: ΔI
- HB, FB, PP: $\frac{\Delta I}{2}$

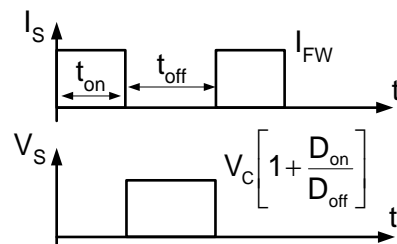
Switch Utilization

Important consideration: $V_s(\text{off}), I_s(\text{on})$

Assumption:

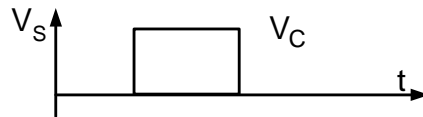
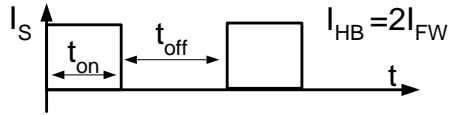
- Same input and output power
- Same input voltage

FORWARD

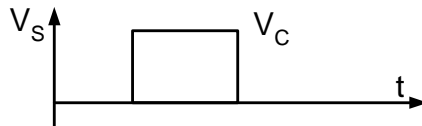
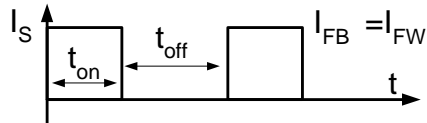




Waveforms



HB



FB



Types of PWM converters Comparison chart

Converter	Sw current	Sw voltage
Buck	I_o	V_{in}
Boost	$I_o(D_{on}/D_{off})$	V_o
Buck-Boost	$I_o(D_{on}/D_{off})$	$V_{in} + V_o$
C'uk	$I_{in} + I_o$	$V_{in} + V_o$
SEPIC	$I_{in} + I_o$	$V_{in} + V_o$
Forward	$I_o * (n_2/n_1)$	$V_{in} + V_{rst}$
Flyback	$I_o * (n_2/n_1)(D_{on}/D_{off})$	$V_{in} + V_o * (n_1/n_2)$
HB	$2I_o * (n_2/n_1)$	V_{in}
FB	$I_o * (n_2/n_1)$	$V_{in}/2$
PP	$I_o * (n_2/n_1)$	$2V_{in}$



TABLE 1.3 Transistor and Diode Requirements for Switching Converters

CIRCUIT CONFIGURATION	BUCK STEP-DOWN	BUCK-BOOST	BUCK-BOOST
TYPE OF CONVERTER	BUCK STEP-DOWN	BUCK-BOOST	BUCK-BOOST
IDEAL TRANSFORMER FUNCTION	$\frac{V_o}{V_i} = \frac{D}{1-D}$	$\frac{V_o}{V_i} = \frac{D}{1-D}$	$\frac{V_o}{V_i} = \frac{D}{1-D}$
COLLECTOR CURRENT $I_{C,avg}$	$I_{C,avg} = I_o + I_{L,avg}$	$I_{C,avg} = I_o \left(\frac{1}{1-D} \right)$	$I_{C,avg} = I_o \left(\frac{1}{1-D} \right)$
COLLECTOR VOLTAGE RATING	$V_{C,peak} = V_i$	$V_{C,peak} = V_i + V_o$	$V_{C,peak} = V_i + V_o$
DIODE CURRENTS	$I_{D,avg} = I_o \left(\frac{1}{1-D} \right)$	$I_{D,avg} = I_o$	$I_{D,avg} = I_o$
DIODE VOLTAGES (Peak)	$V_{D,peak} = V_o$	$V_{D,peak} = V_o$	$V_{D,peak} = V_o + V_i$
VOLTAGE AND CURRENT WAVEFORMS			
ADVANTAGES	ONLY FREQUENCY RANGE IS LIMITED BY TRANSFORMER. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.	NO SPECIAL DIODES OR TRANSFORMERS. SIMPLE AND PRESENTS LOW TRANSFORMER COST.	ONLY FREQUENCY RANGE IS LIMITED BY TRANSFORMER. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.
DISADVANTAGES	NO FREQUENCY RANGE LIMIT AND ONLY FREQUENCY RANGE LIMIT. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.	NO FREQUENCY RANGE LIMIT AND ONLY FREQUENCY RANGE LIMIT. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.	NO FREQUENCY RANGE LIMIT AND ONLY FREQUENCY RANGE LIMIT. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.

TABLE 1.3 (Continued)

CIRCUIT CONFIGURATION	FLYBACK	FORWARD
TYPE OF CONVERTER	FLYBACK	FORWARD
IDEAL TRANSFORMER FUNCTION	$\frac{V_o}{V_i} = \frac{D}{1-D}$	$\frac{V_o}{V_i} = \frac{D}{1-D}$
COLLECTOR CURRENT $I_{C,avg}$	$I_{C,avg} = I_o \left(\frac{1}{1-D} \right)$	$I_{C,avg} = I_o \left(\frac{1}{1-D} \right)$
COLLECTOR VOLTAGE RATING	$V_{C,peak} = V_i + V_o$	$V_{C,peak} = V_i + V_o$
DIODE CURRENTS	$I_{D,avg} = I_o$	$I_{D,avg} = I_o$
DIODE VOLTAGES (Peak)	$V_{D,peak} = V_o$	$V_{D,peak} = V_o$
VOLTAGE AND CURRENT WAVEFORMS		
ADVANTAGES	SIMPLE. MULTIPLE OUTPUTS ARE POSSIBLE. TRANSFORMER APPROXIMATE QUALITY FACTOR IS 0.5. LOW OUTPUT RATIO.	SIMPLE. MULTIPLE OUTPUTS ARE POSSIBLE. COLLECTOR CURRENT REDUCED BY FACTOR OF 0.5. LOW OUTPUT RATIO.
DISADVANTAGES	NO FREQUENCY RANGE LIMIT AND ONLY FREQUENCY RANGE LIMIT. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.	NO FREQUENCY RANGE LIMIT AND ONLY FREQUENCY RANGE LIMIT. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.




TABLE 1.3 (Continued)

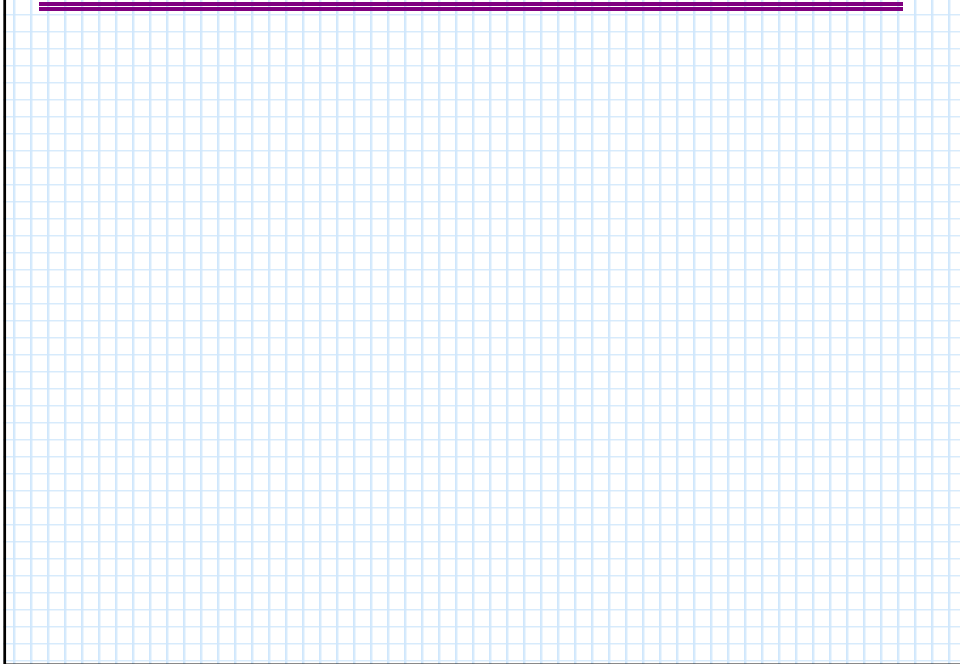
CIRCUIT CONFIGURATION	HALF-BRIDGE	FULL-BRIDGE
TYPE OF CONVERTER	HALF-BRIDGE	FULL-BRIDGE
IDEAL TRANSFORMER FUNCTION	$\frac{V_o}{V_i} = \frac{D}{1-D}$	$\frac{V_o}{V_i} = \frac{D}{1-D}$
COLLECTOR CURRENT $I_{C,avg}$	$I_{C,avg} = I_o \left(\frac{1}{1-D} \right)$	$I_{C,avg} = I_o \left(\frac{1}{1-D} \right)$
COLLECTOR VOLTAGE RATING	$V_{C,peak} = V_i$	$V_{C,peak} = V_i$
DIODE CURRENTS	$I_{D,avg} = I_o \left(\frac{1}{1-D} \right)$	$I_{D,avg} = I_o$
DIODE VOLTAGES (Peak)	$V_{D,peak} = V_o$	$V_{D,peak} = V_o$
VOLTAGE AND CURRENT WAVEFORMS		
ADVANTAGES	SIMPLE. ONE TRANSFORMER WITH LOW TRANSFORMER COST. TRANSFORMER APPROXIMATE QUALITY FACTOR IS 0.5. LOW OUTPUT RATIO.	SIMPLE. TWO TRANSFORMERS WITH LOW TRANSFORMER COST. TRANSFORMER APPROXIMATE QUALITY FACTOR IS 0.5. LOW OUTPUT RATIO.
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TABLE 1.3 (Continued)

CIRCUIT CONFIGURATION	BUCK-BOOST	BUCK-BOOST	BUCK-BOOST
TYPE OF CONVERTER	BUCK-BOOST	BUCK-BOOST	BUCK-BOOST
IDEAL TRANSFORMER FUNCTION	$\frac{V_o}{V_i} = \frac{D}{1-D}$	$\frac{V_o}{V_i} = \frac{D}{1-D}$	$\frac{V_o}{V_i} = \frac{D}{1-D}$
COLLECTOR CURRENT $I_{C,avg}$	$I_{C,avg} = I_o \left(\frac{1}{1-D} \right)$	$I_{C,avg} = I_o \left(\frac{1}{1-D} \right)$	$I_{C,avg} = I_o \left(\frac{1}{1-D} \right)$
COLLECTOR VOLTAGE RATING	$V_{C,peak} = V_i + V_o$	$V_{C,peak} = V_i + V_o$	$V_{C,peak} = V_i + V_o$
DIODE CURRENTS	$I_{D,avg} = I_o$	$I_{D,avg} = I_o$	$I_{D,avg} = I_o$
DIODE VOLTAGES (Peak)	$V_{D,peak} = V_o$	$V_{D,peak} = V_o$	$V_{D,peak} = V_o$
VOLTAGE AND CURRENT WAVEFORMS			
ADVANTAGES	SIMPLE. ONE TRANSFORMER WITH LOW TRANSFORMER COST. TRANSFORMER APPROXIMATE QUALITY FACTOR IS 0.5. LOW OUTPUT RATIO.	SIMPLE. ONE TRANSFORMER WITH LOW TRANSFORMER COST. TRANSFORMER APPROXIMATE QUALITY FACTOR IS 0.5. LOW OUTPUT RATIO.	SIMPLE. ONE TRANSFORMER WITH LOW TRANSFORMER COST. TRANSFORMER APPROXIMATE QUALITY FACTOR IS 0.5. LOW OUTPUT RATIO.
DISADVANTAGES	NO FREQUENCY RANGE LIMIT AND ONLY FREQUENCY RANGE LIMIT. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.	NO FREQUENCY RANGE LIMIT AND ONLY FREQUENCY RANGE LIMIT. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.	NO FREQUENCY RANGE LIMIT AND ONLY FREQUENCY RANGE LIMIT. TRANSFORMER COST IS SIGNIFICANT. REGULATED OUTPUT.

*For reliable operation, it is suggested and recommended that all voltage and current ratings be increased to 125% of the required maximum.

 **Mor M. Peretz, Switch-Mode Power Supplies** **[6-21]**



 **Mor M. Peretz, Switch-Mode Power Supplies** **[6-22]**

