TSTE19 Power Electronics

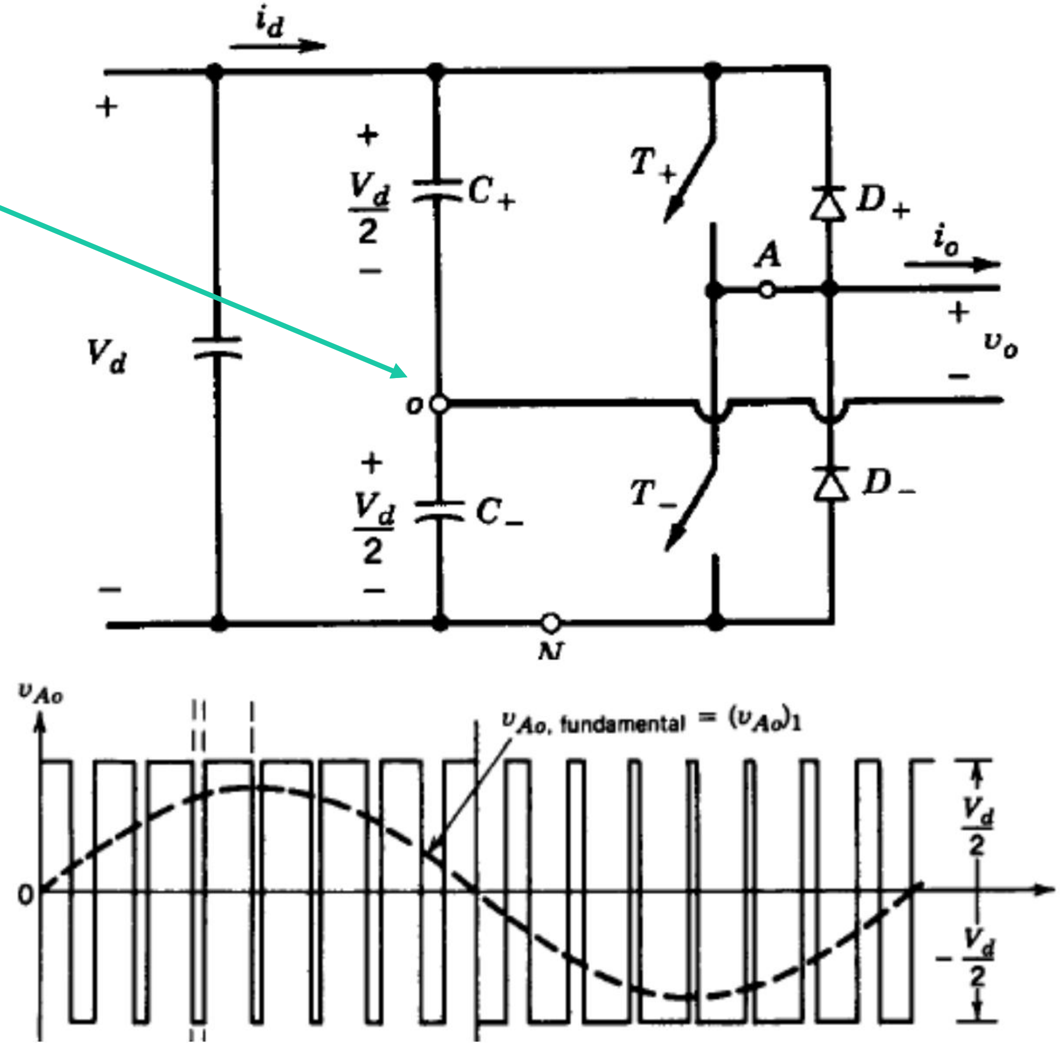
- Lecture 8
- Tomas Jonsson
- ISY/EKS

Outline

- DC-AC switching inverters 2
- Full-bridge inverter
  - Harmonics
  - DC-side current

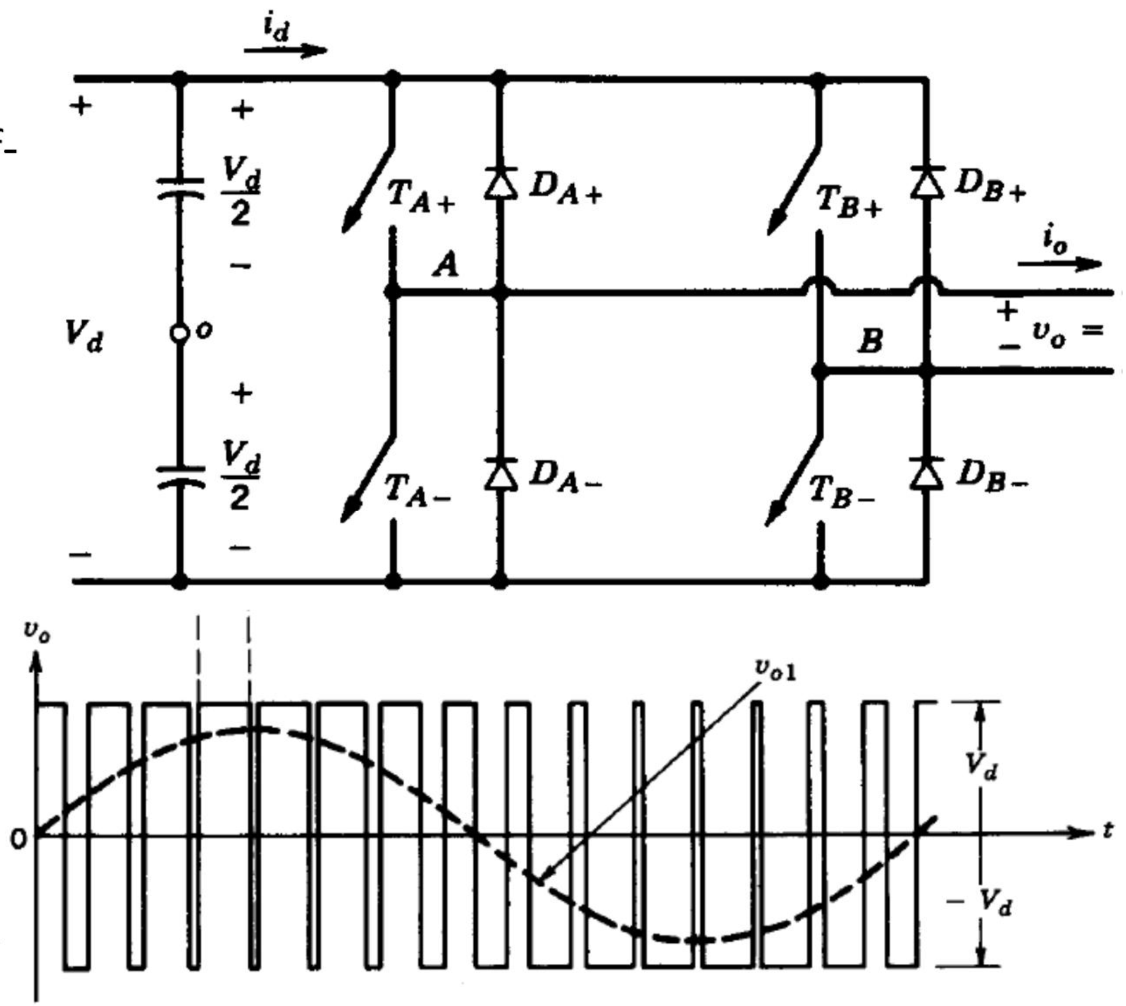
Half-bridge (2-level) converter

- DC-side midpoint '0' reference point for ac-output
- Output voltage switched between $+\frac{V_d}{2}$ and $-\frac{V_d}{2}$



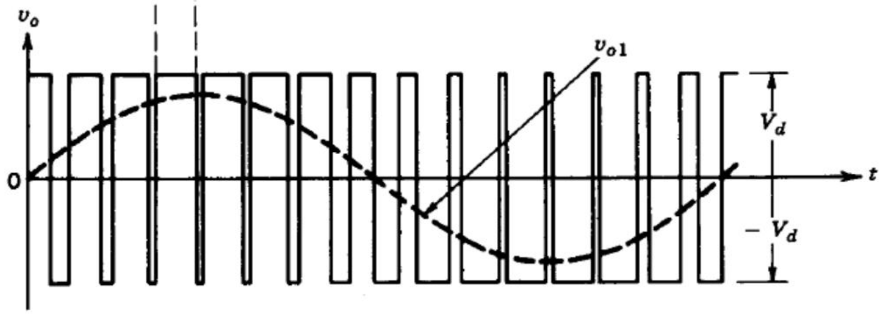
Full-bridge inverter

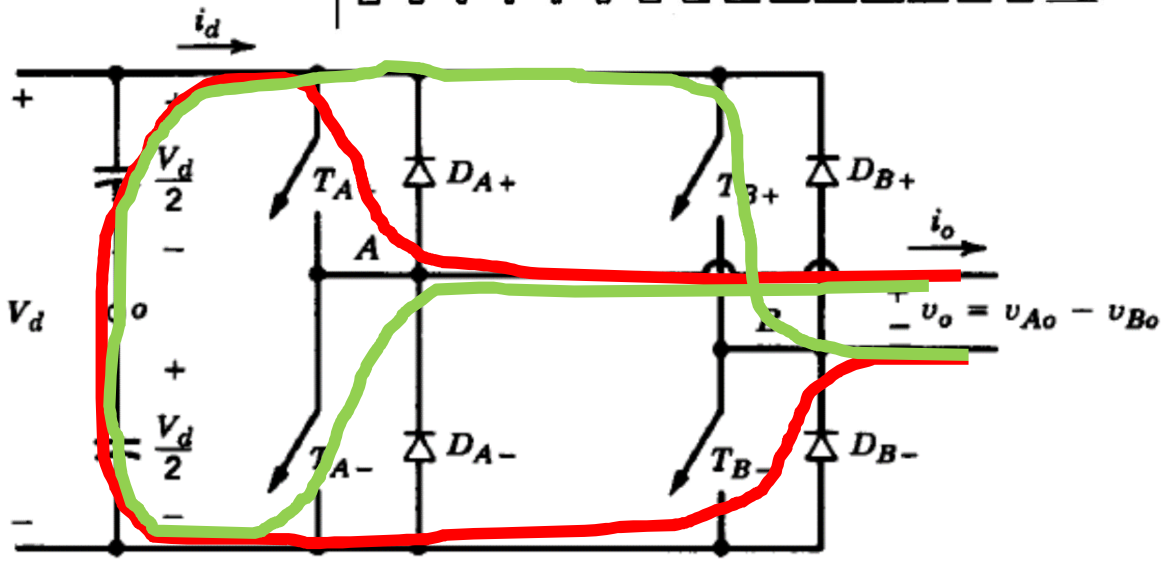
- Maximum output voltage doubled compared to half-bridge inverter
- No need for midpoint voltage



PWM switching strategies

- Bipolar voltage switching
  - Both pairs (TA+, TB-) and (TA-, TB+) controlled simultaneous
- 2 possible switch configurations
  1. TA+, TB-: vA-vB positive
  2. TA-, TB+: vA-vB negative





PWM bipolar switching

- Both legs switch at the same time

$m_a < 1.0$

$$\hat{V}_{o1} = m_a V_d$$

$m_a > 1.0$

$$V_d < \hat{V}_{o1} < \frac{4}{\pi} V_d$$

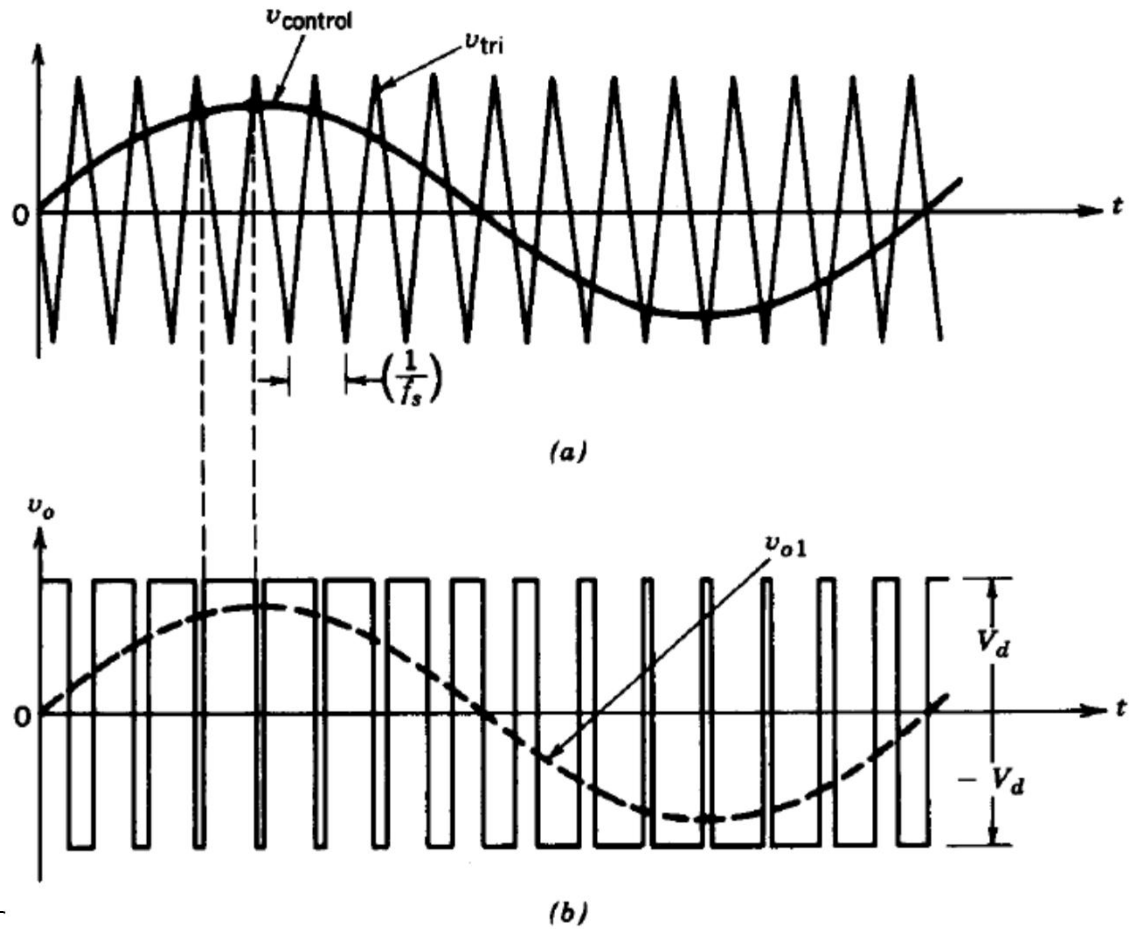
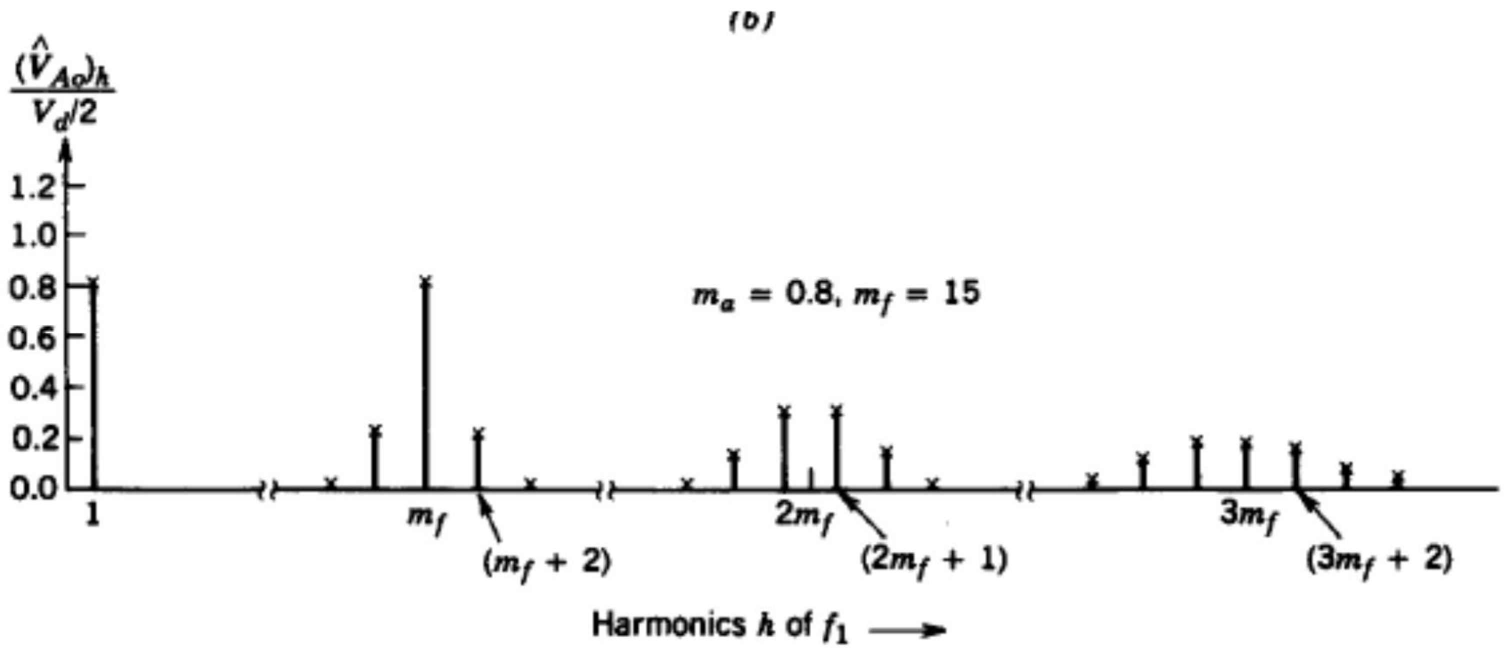


Figure 8-12 PWM with bipolar voltage switching.

PWM modulation harmonics

- Harmonics as sidebands around multiples of switching frequency



Harmonics due to m_a and m_f>9

- For m_f < 9 is harmonics almost independent of m_f
- Choose m_f odd integer
  - Odd symmetry
  - Half-wave symmetry
  - Only odd harmonics
  - Even harmonics = 0
  - With $v_A = \hat{V}_A \sin \omega t$ all harmonics $\sin h\omega t$

Table 8-1 Generalized Harmonics of v_{Ao} for a Large m_f.

h \ m_a	0.2	0.4	0.6	0.8	1.0
1 Fundamental	0.2	0.4	0.6	0.8	1.0
m_f	1.242	1.15	1.006	0.818	0.601
$m_f \pm 2$	0.016	0.061	0.131	0.220	0.318
$m_f \pm 4$					0.018
$2m_f \pm 1$	0.190	0.326	0.370	0.314	0.181
$2m_f \pm 3$		0.024	0.071	0.139	0.212
$2m_f \pm 5$				0.013	0.033
$3m_f$	0.335	0.123	0.083	0.171	0.113
$3m_f \pm 2$	0.044	0.139	0.203	0.176	0.062
$3m_f \pm 4$		0.012	0.047	0.104	0.157
$3m_f \pm 6$				0.016	0.044
$4m_f \pm 1$	0.163	0.157	0.008	0.105	0.068
$4m_f \pm 3$	0.012	0.070	0.132	0.115	0.009
$4m_f \pm 5$			0.034	0.084	0.119
$4m_f \pm 7$				0.017	0.050

Note: $(\hat{V}_{Ao})_h/\frac{1}{2}V_d$ [$= (\hat{V}_{AN})_h/\frac{1}{2}V_d$] is tabulated as a function of m_a.

DC-side current

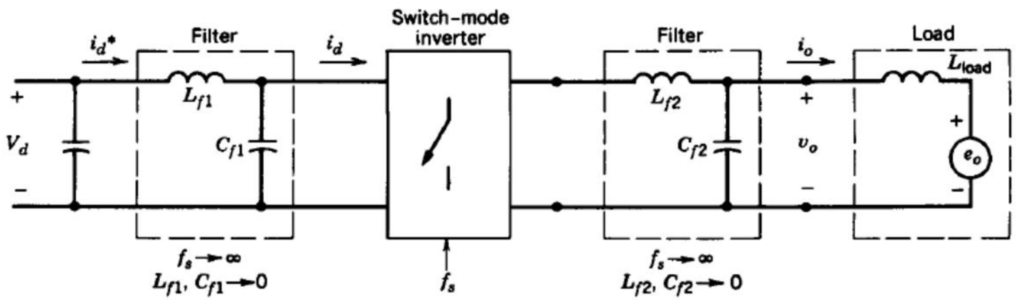
$$v_o(t) = \sqrt{(2)}V_o \sin \omega_1 t$$
$$i_o(t) = \sqrt{(2)}I_o \sin(\omega_1 t - \varphi)$$
$$V_d i^*{}_d(t) = v_o(t)\, i_o(t)$$

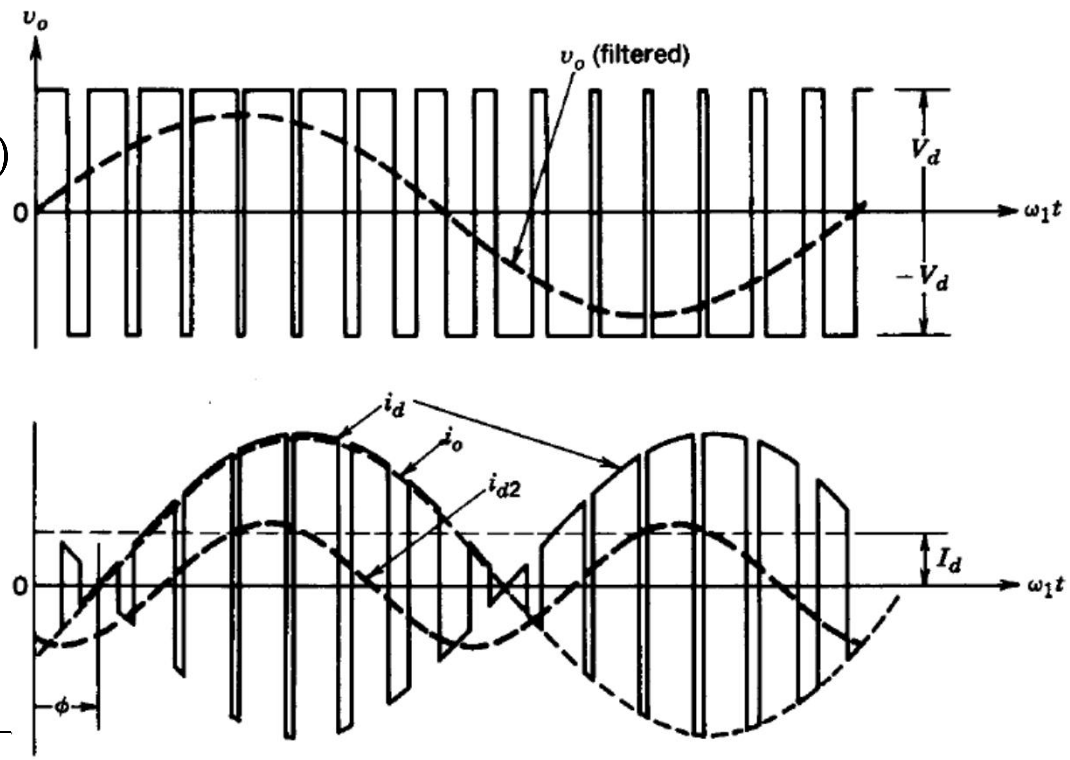
$$i^*{}_d(t) = I_d - \sqrt{(2)}I_{d2}\cos(2\omega_1 t - \varphi)$$

where

$$I_d = \frac{V_o I_o}{V_d}\cos\varphi$$

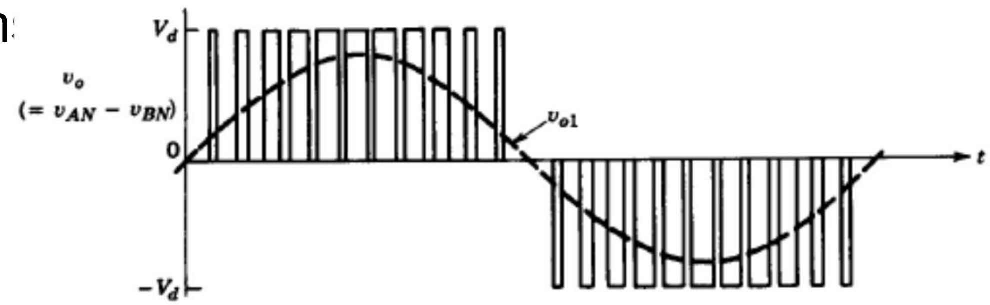
$$I_{d2} = \frac{1}{\sqrt{(2)}}\frac{V_o I_o}{V_d}$$



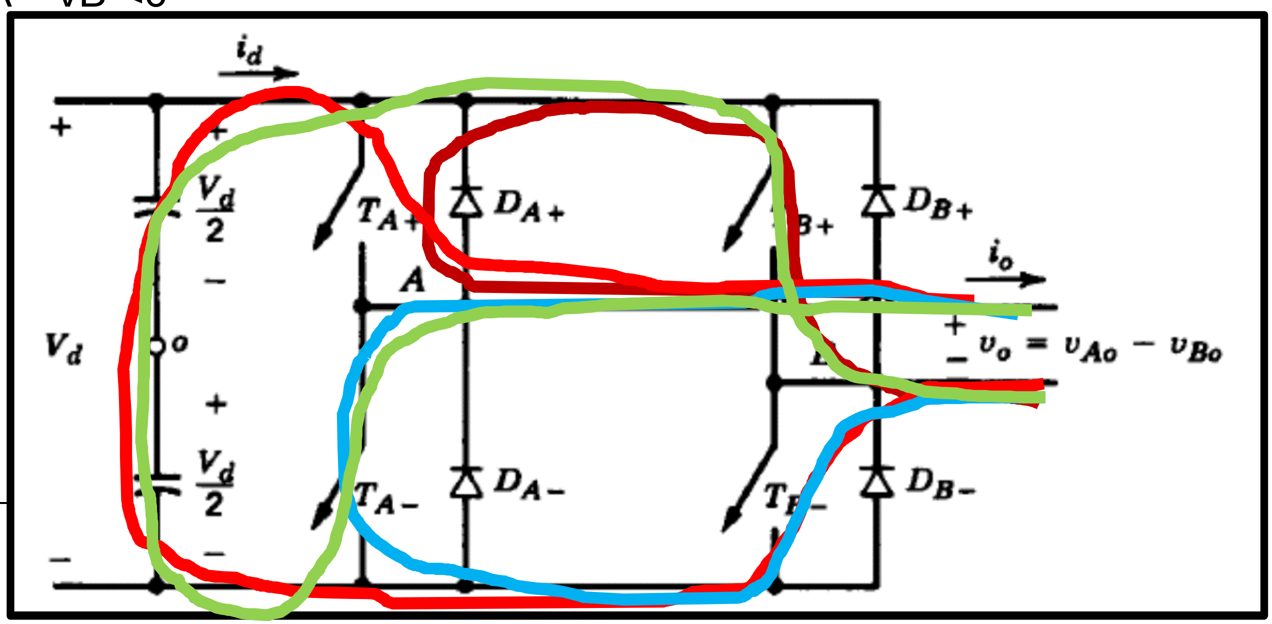


Unipolar (3-level) voltage switching

- Switches in each inverter leg (A and B) are controlled independently of the other leg
- 4 possible switch configurations

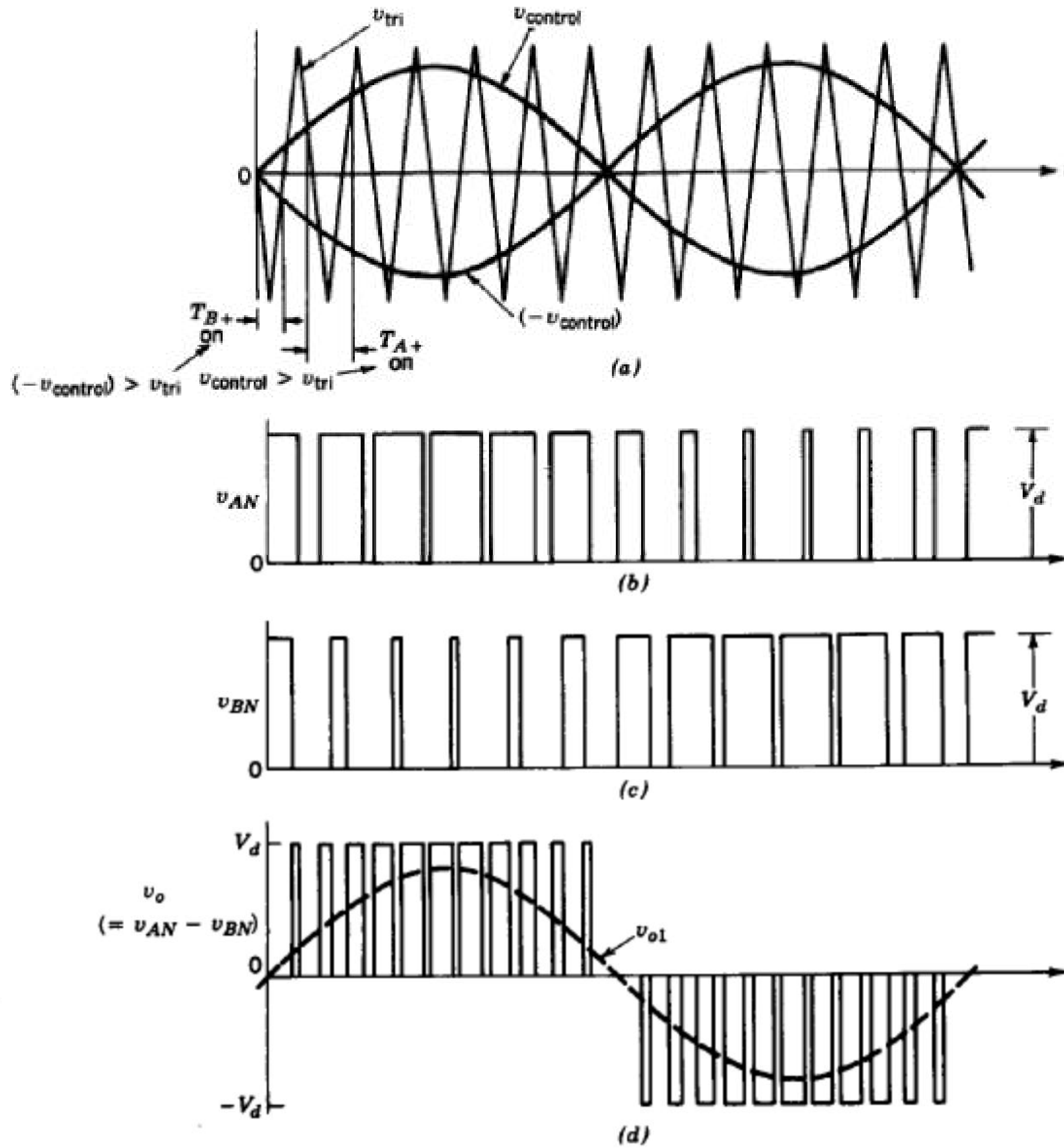


1. TA+, TB+: vA - vB = 0
2. TA+, TB-: vA - vB > 0
3. TA-, TB-: vA - vB = 0
4. TA-, TB+: vA – vB <0



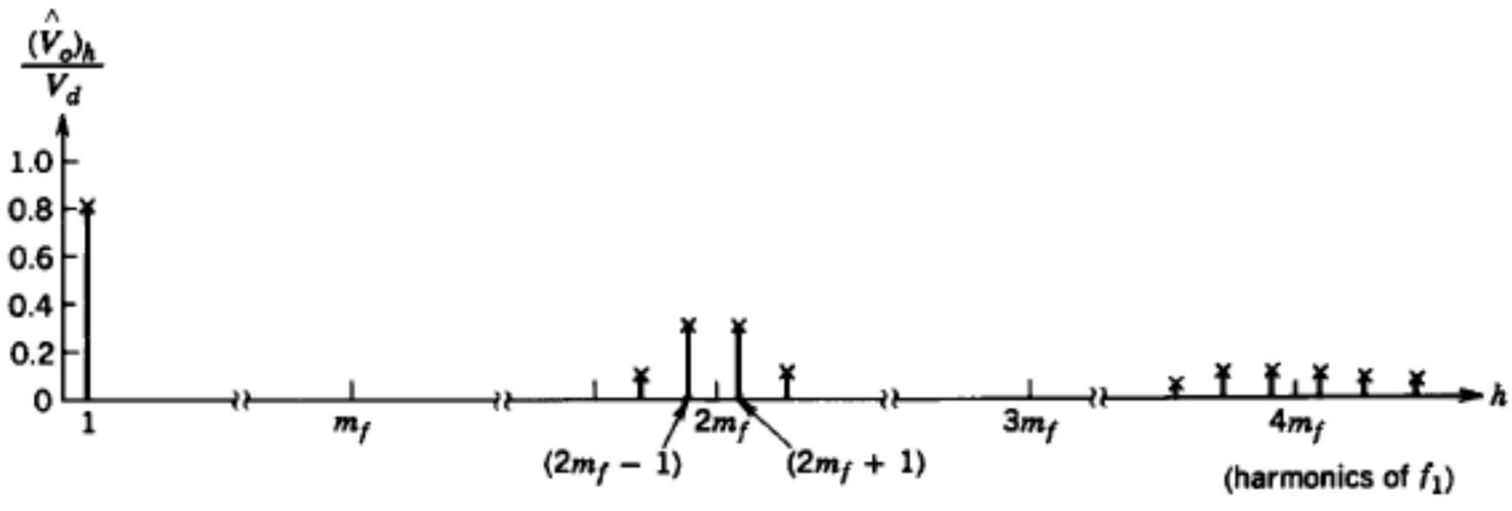
Unipolar PWM-control

- One leg controlled by $v_{control}$
- Other leg controlled by $-v_{control}$
- Four states



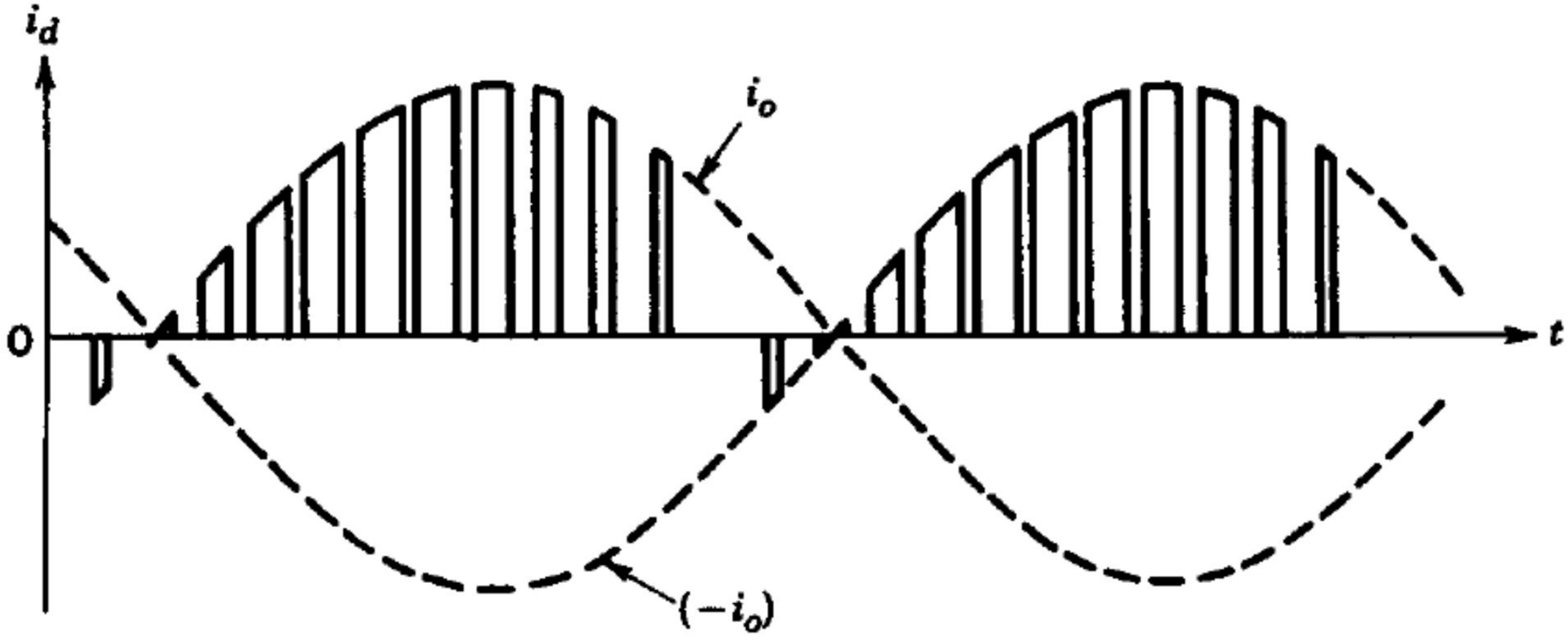
PWM unipolar switching harmonics

- Harmonics at twice the switching frequency
- m_f even makes switching frequency harmonic cancel out



PWM unipolar switching dc current

- Less ripple compared to bipolar switching



8-1

- In a single-phase full-bridge PWM inverter, the input dc voltage varies in a range of 295-325 V. Because of the low distortion required in the output *vow*, $m_a < 1.0$.
  a) What is the highest V_{o1} that can be obtained and stamped on its nameplate as its voltage rating?
  b) Its nameplate volt-ampere rating is specified as 2000 VA, that is, $V_{o1,max}\, I_{o1,max} = 2000$ VA, where i_o is assumed to be sinusoidal. Calculate the combined switch utilization ratio when the inverter is supplying its rated volt-amperes.
  c) Compare with results for a half-bridge.

DC/DC-converter control

- Pulse width modulation, PWM,
  to control switching
- Switching frequency f_s

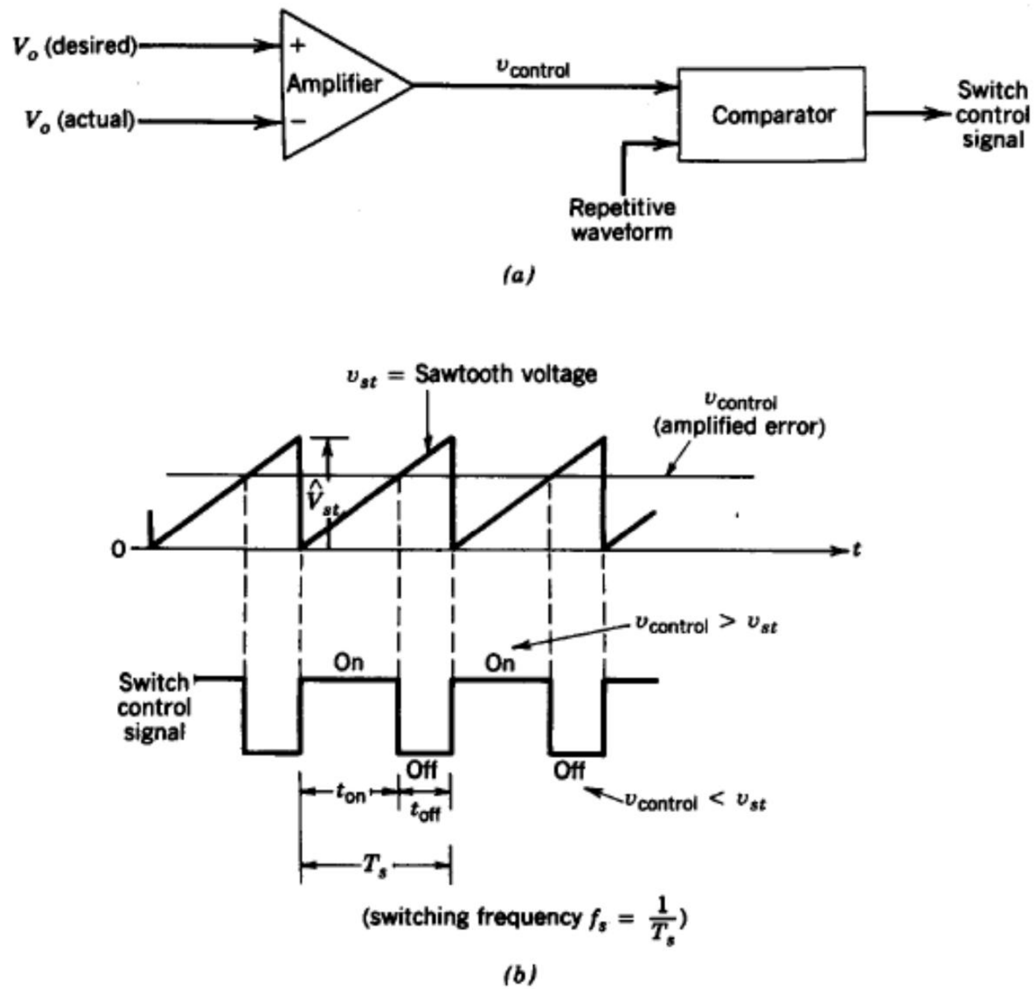
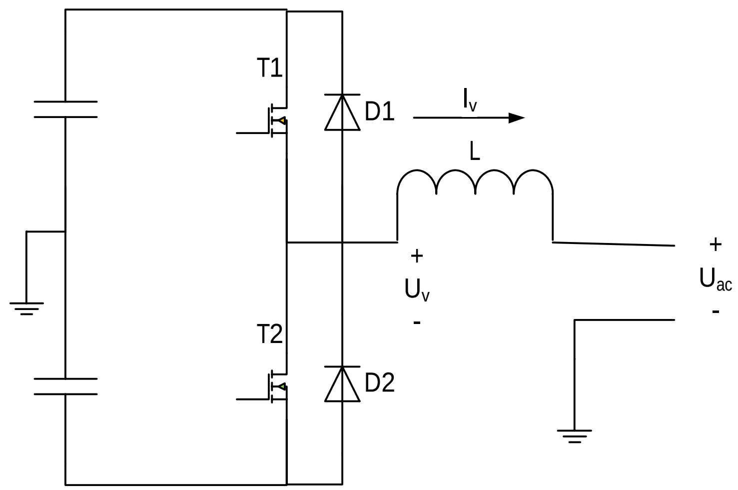


Figure 7-3 Pulse-width modulator: (a) block diagram; (b) comparator signals.



Exersice 8-100

- In a half-bridge converter with U_d=2V and L = 2mH switching is done with m_a=0.8 and m_f=5
- Construct graphically the output voltage and current, u_v and i_v
- $u_L = L\frac{di_L}{dt}$

$$\Delta i_L = \frac{u_v - u_{ac}}{L}\Delta t$$

www.liu.se

LINKÖPING
UNIVERSITY