# **Energoelektronika**

9. Switching DC Power Supplies

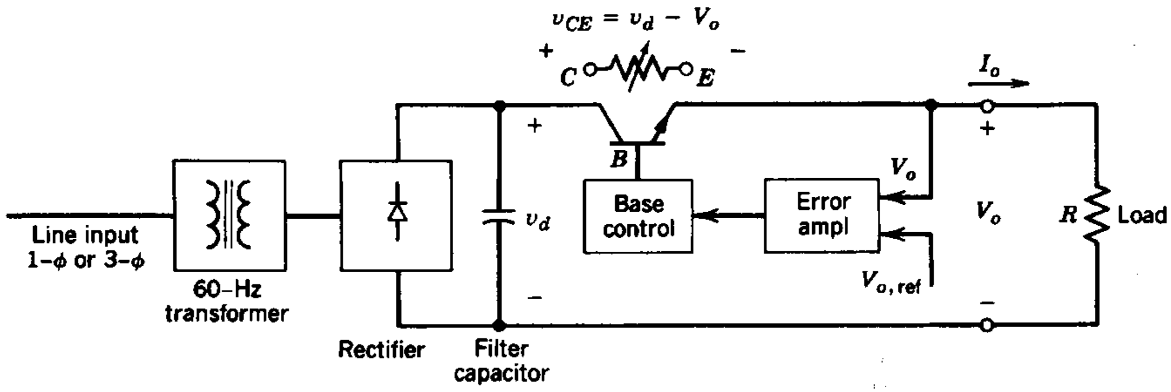
# Plan

**Power supplies**

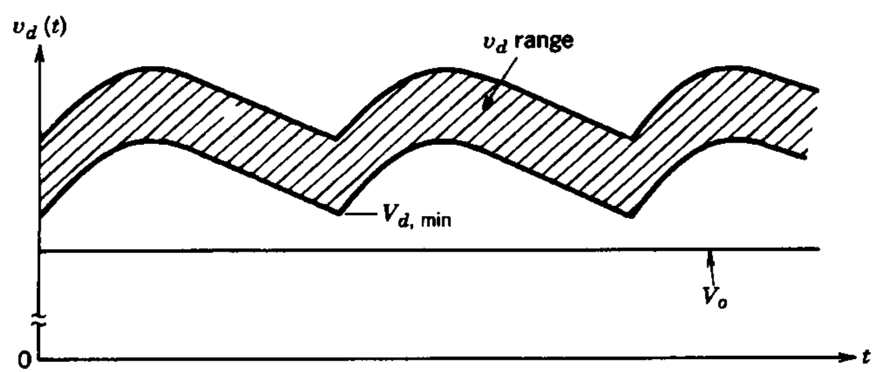
**One of the most important applications of power electronics**

- Linear power supplies
- Switchong power supplies
- Electrical isolation
- Control of switched power supplies
- Power supply protection
- Electrical isloation and feedback loop

# Linear Power Supplies



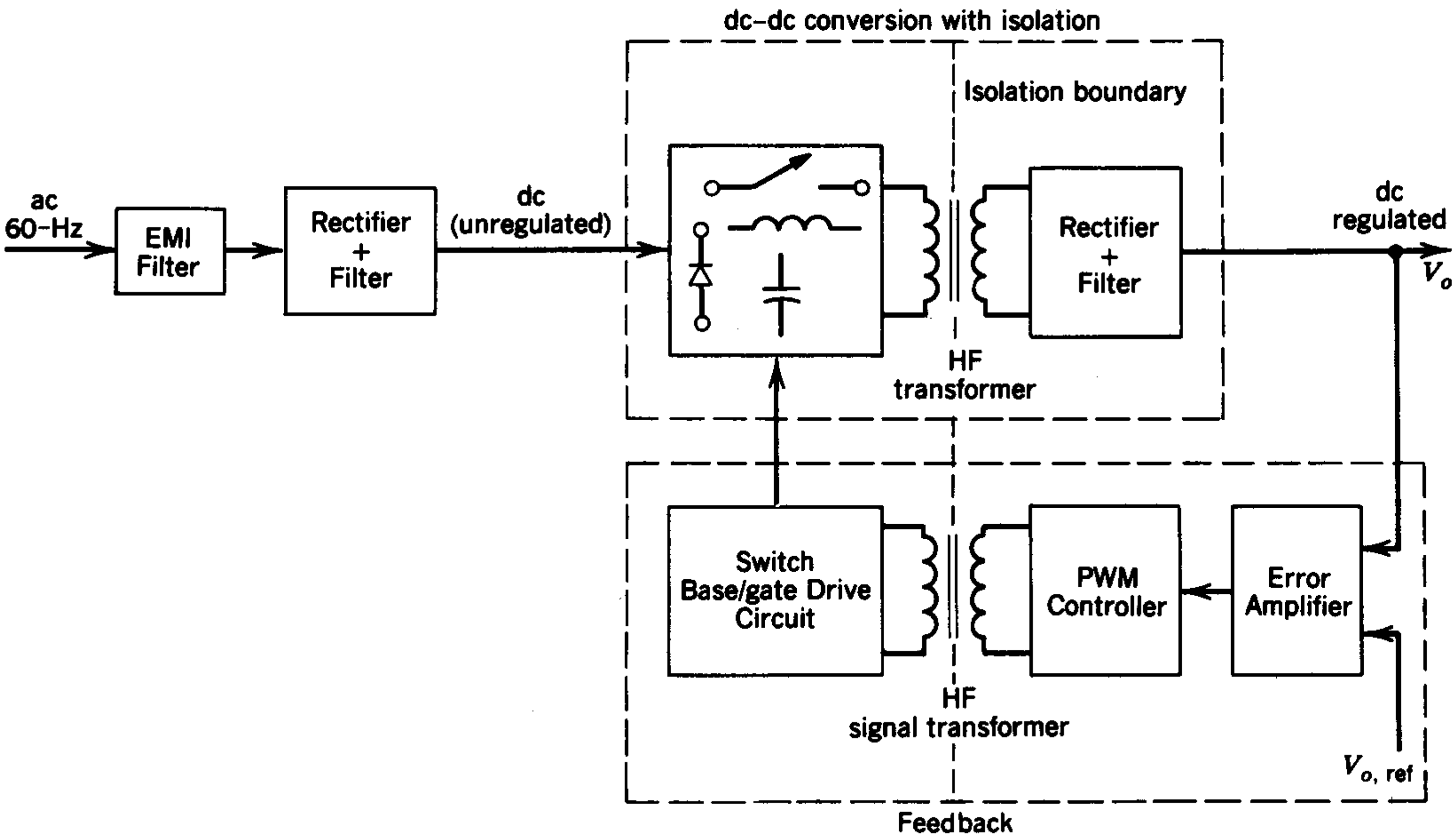

(a)




(b)

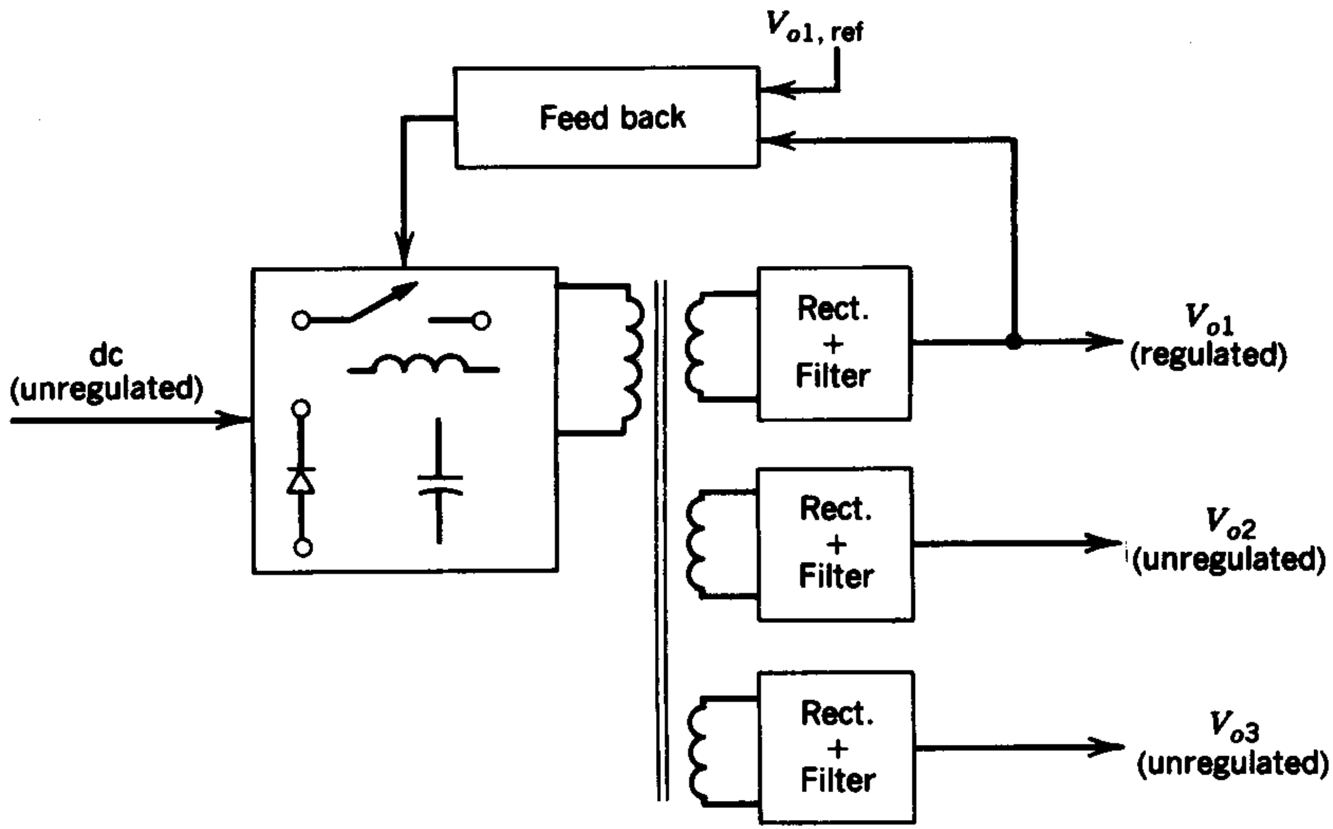
- Very poor efficiency and large weight and size

# Switching DC Power Supply: Block Diagram



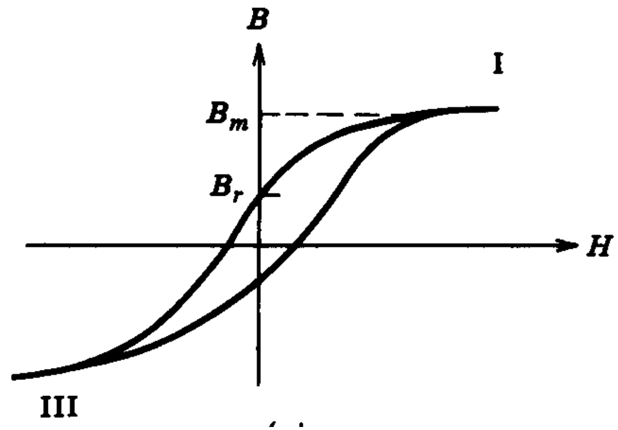

- High efficiency and small weight and size

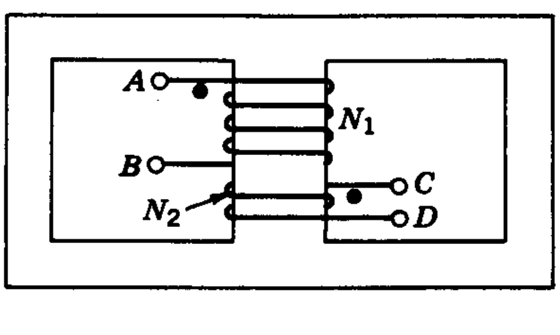
# Switching DC Power Supply – Multiple Outputs

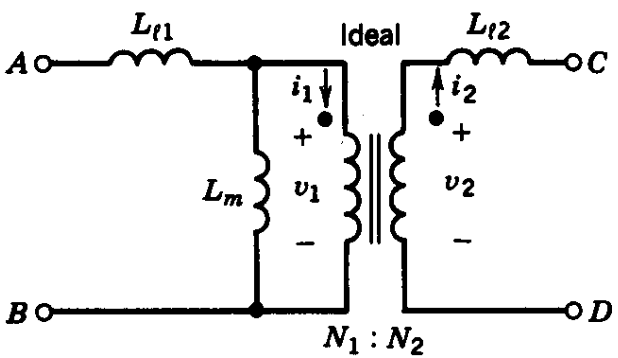



- In most applications, several dc voltages are required, possibly electrically isolated from each other

# Transformer Analysis

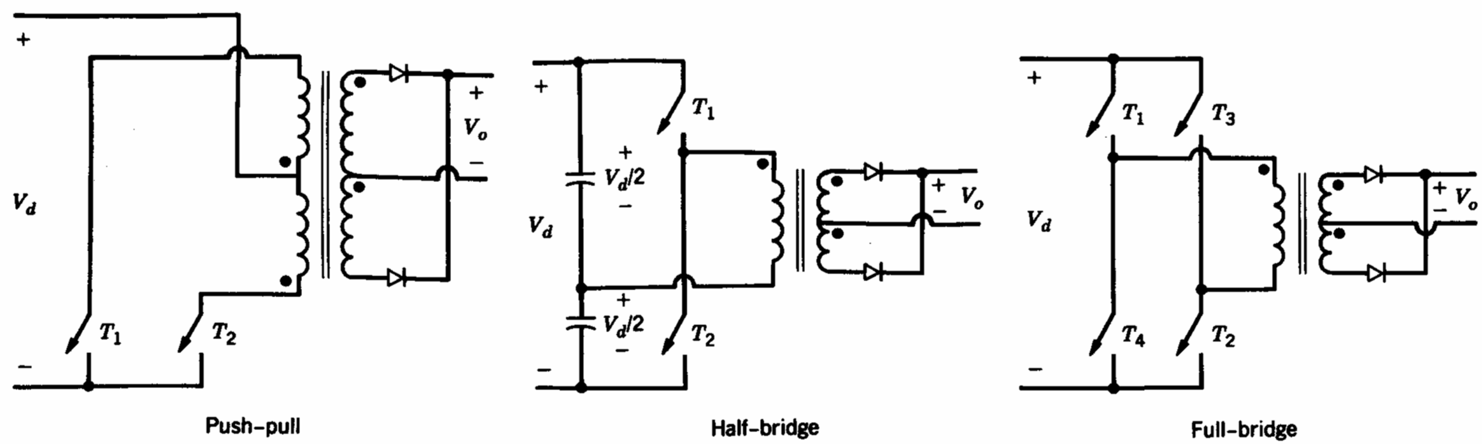


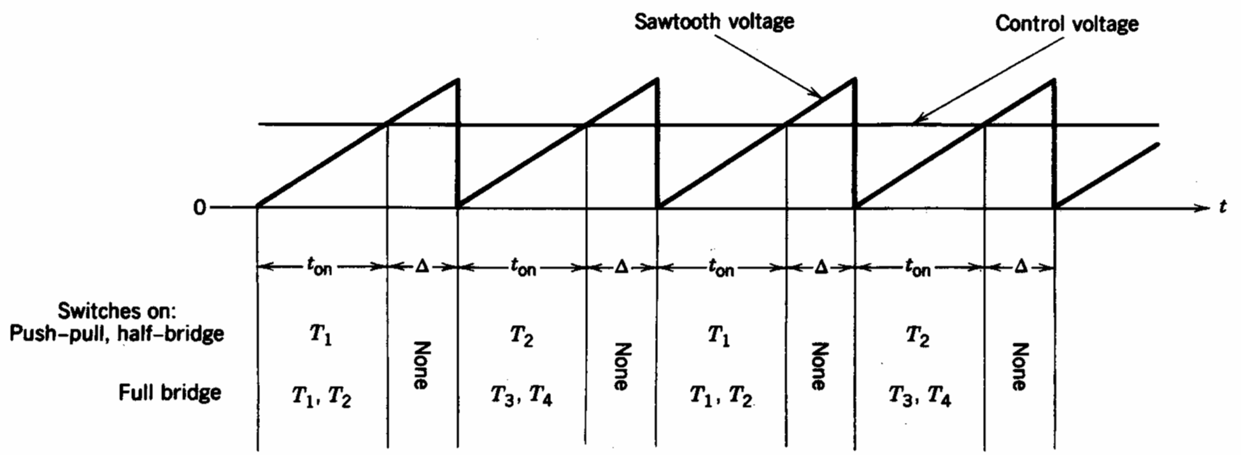




- Needed to discuss high-frequency isolated supplies

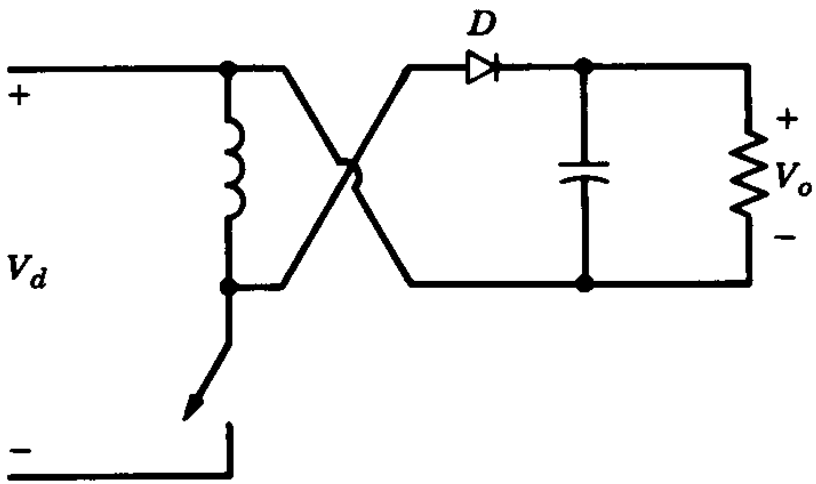
# PWM to Regulate Output

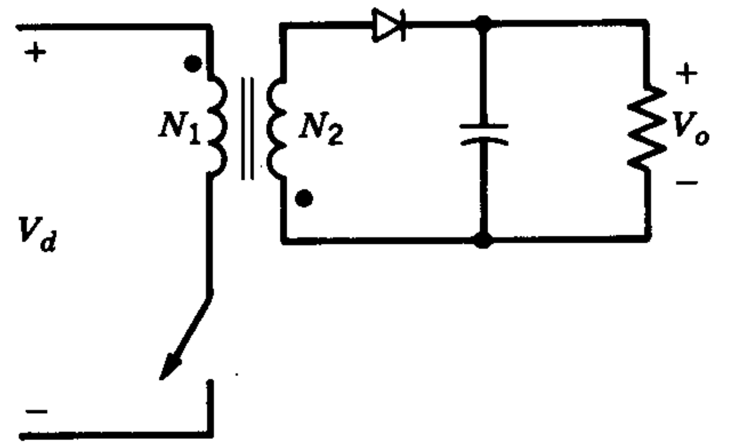



- Basic principle is the same as discussed in DC-AC Converter lecture

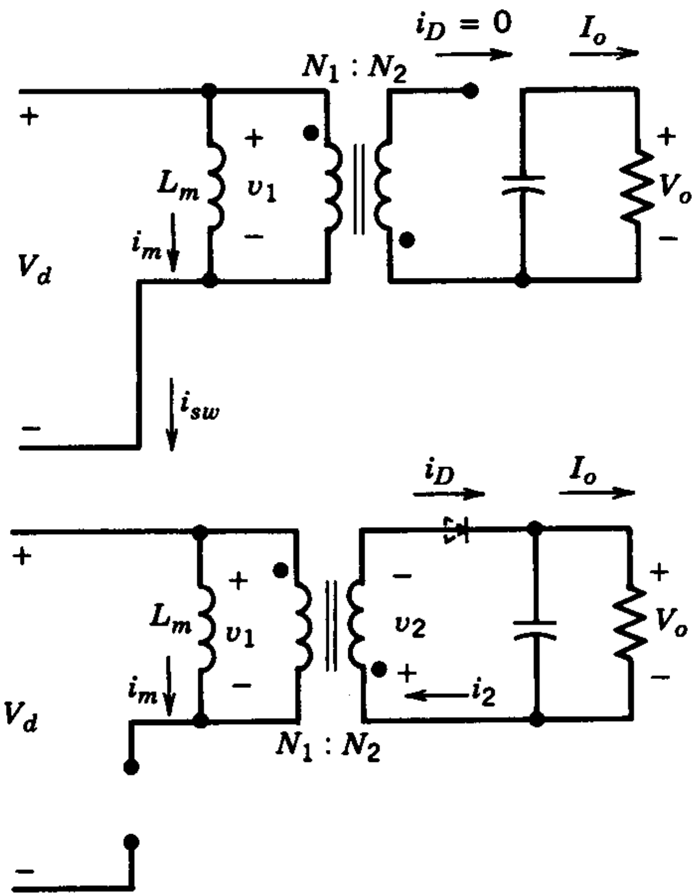
# Flyback Converter




- Derived from buck-boost; very power at small power (> 50 *W*) power levels

# Flyback Converter



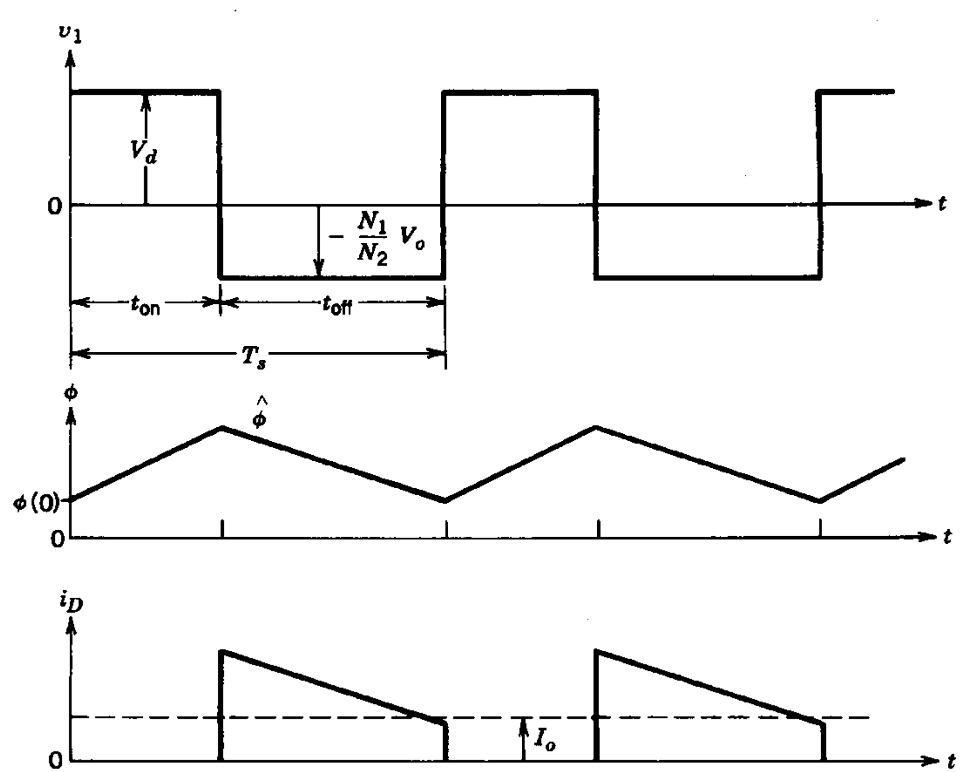
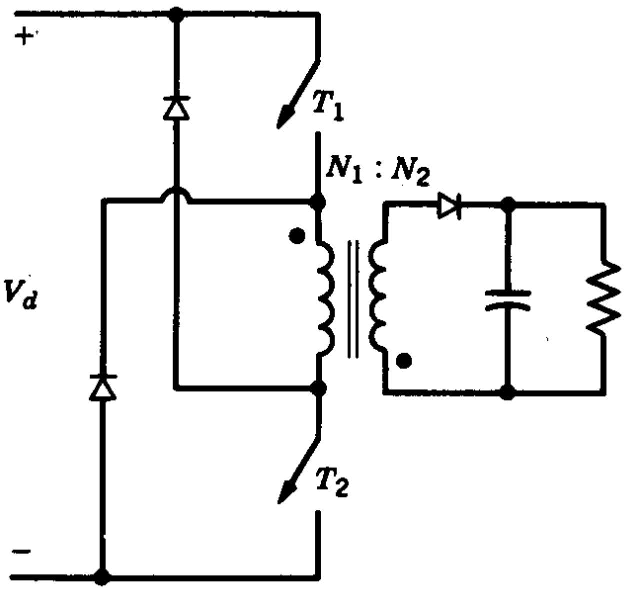



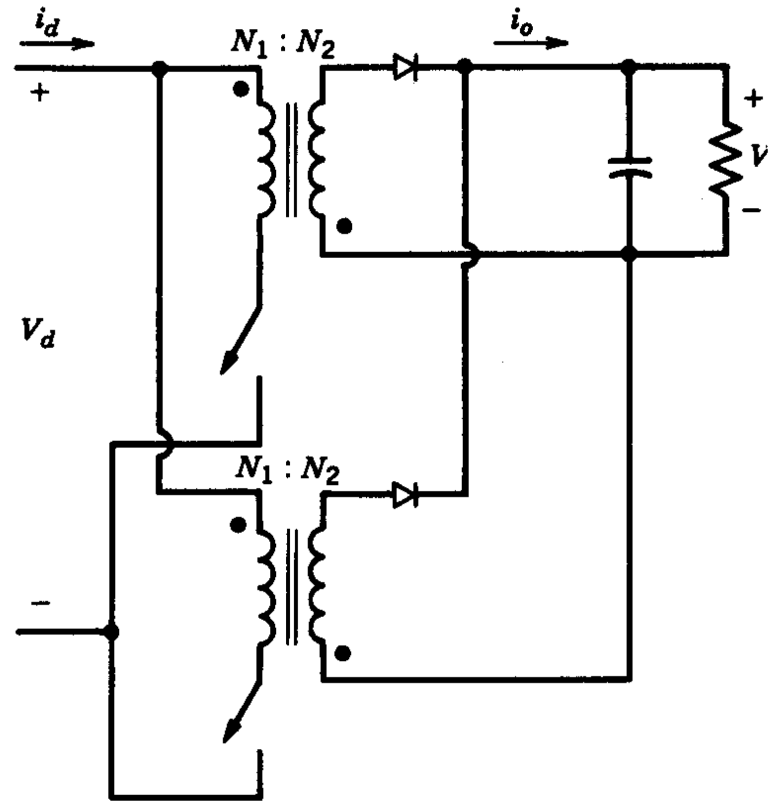

**Figure 10-8** Flyback converter waveforms.

- Switch on and off states
(assuming incomplete core demagnetization)

# Other Flyback Converter Topologies

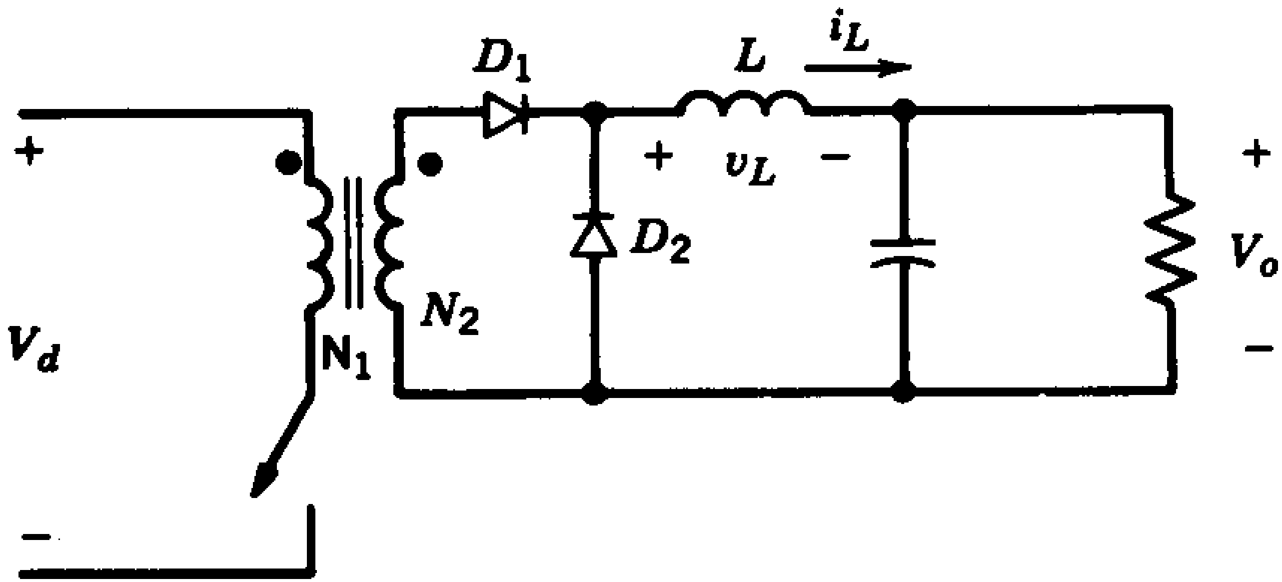


(a)



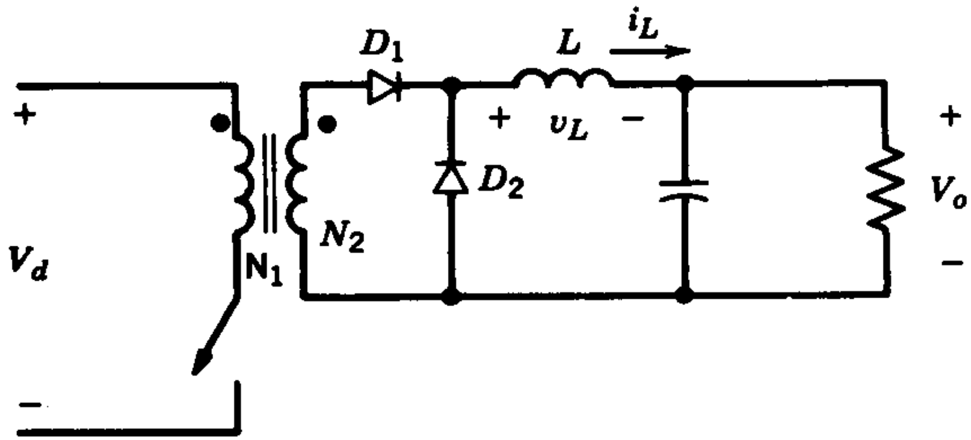

- Not commonly used

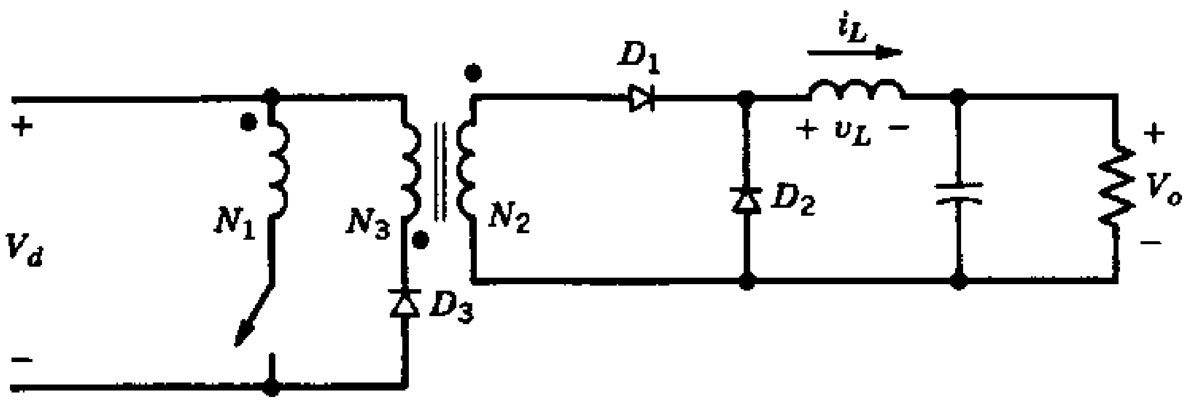
# Forward Converter



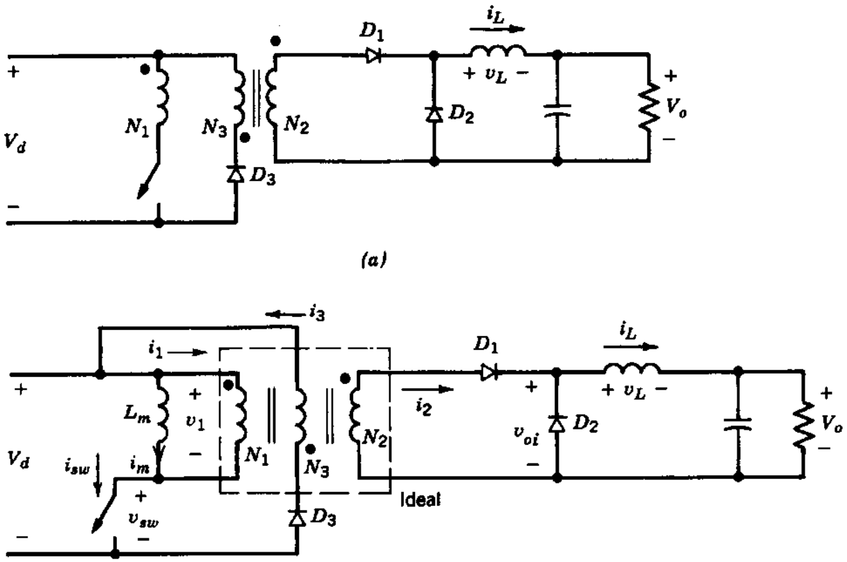

- Derived from Buck; idealized to assume that the transformer is ideal (not possible in practice)

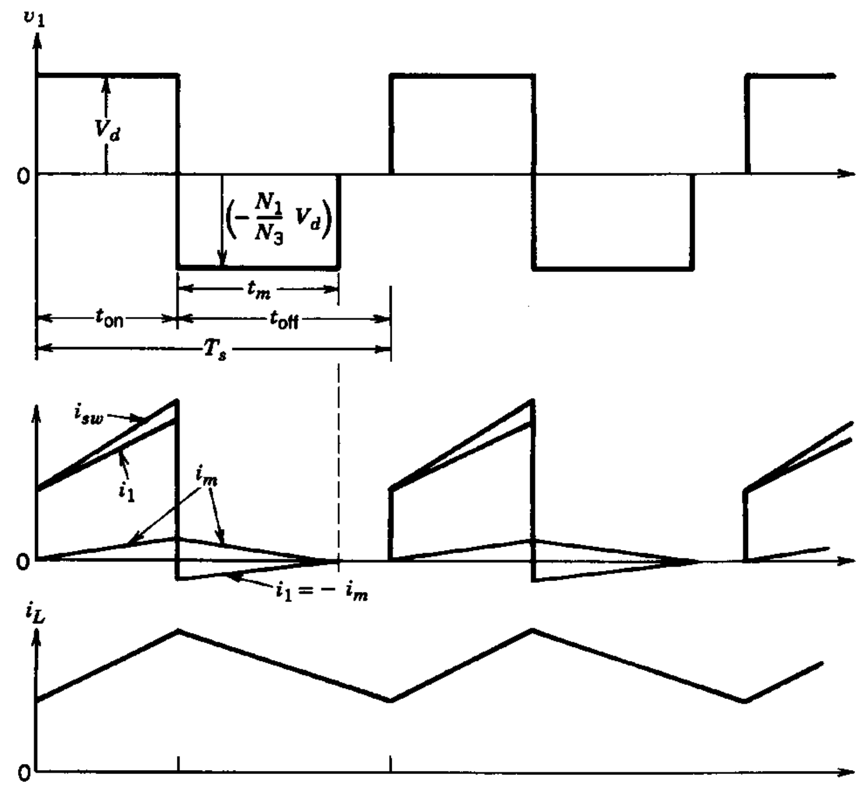
# Forward Converter – in Practice



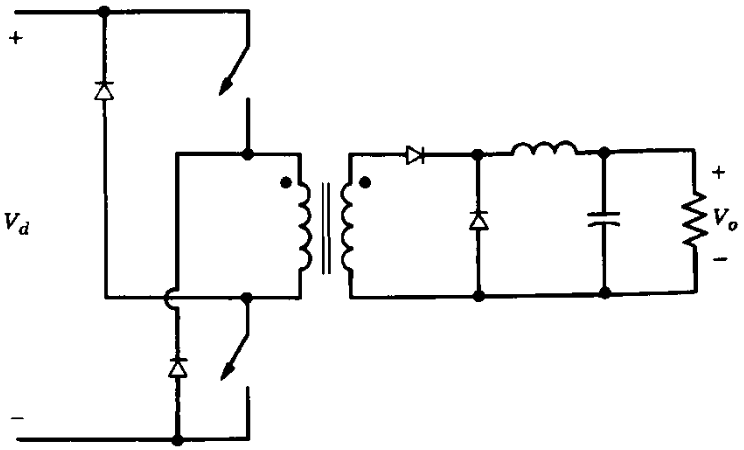
# Practice Forward Converter Waveform

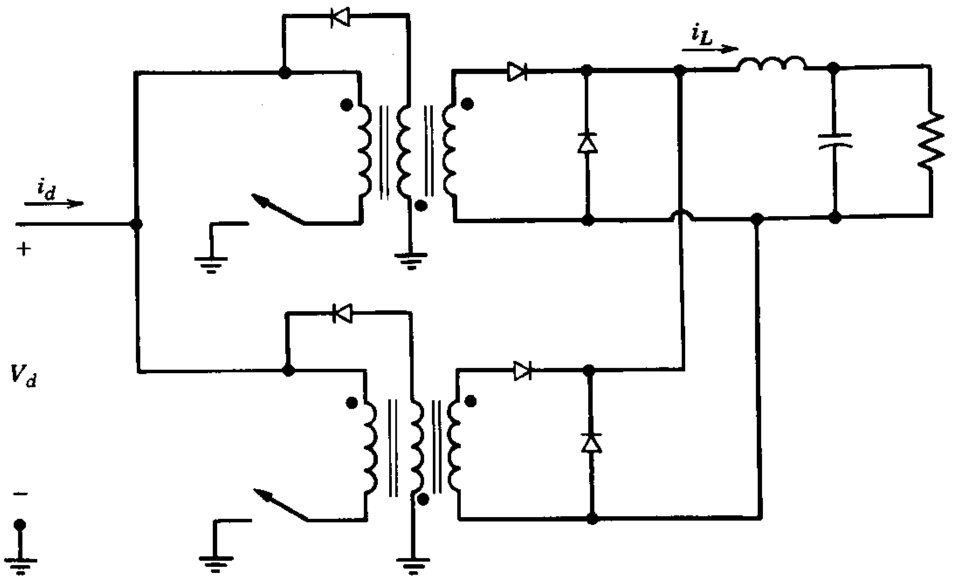


- Switching waveforms
  (assuming incomplete core demagnetization)

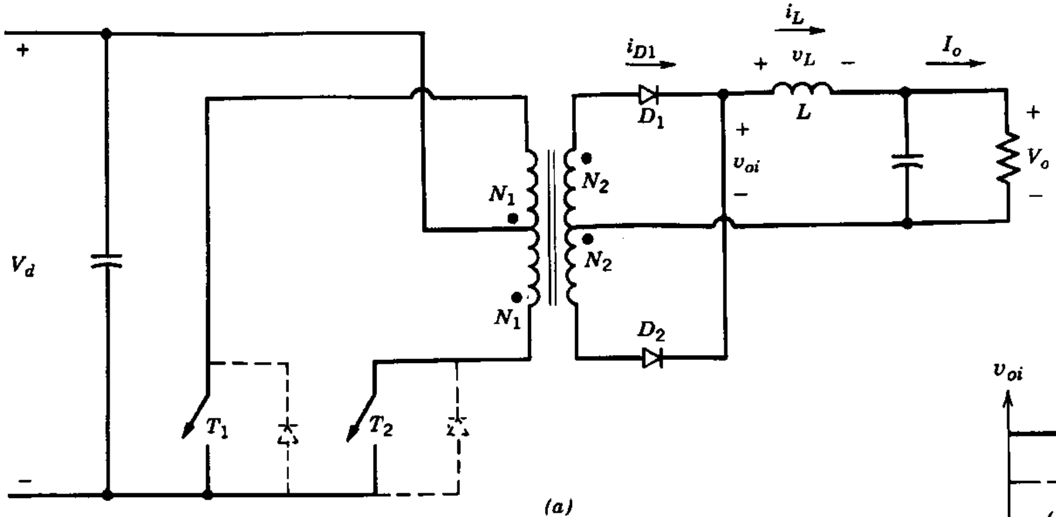
# Forward Converter
# – Other Possible Topologies

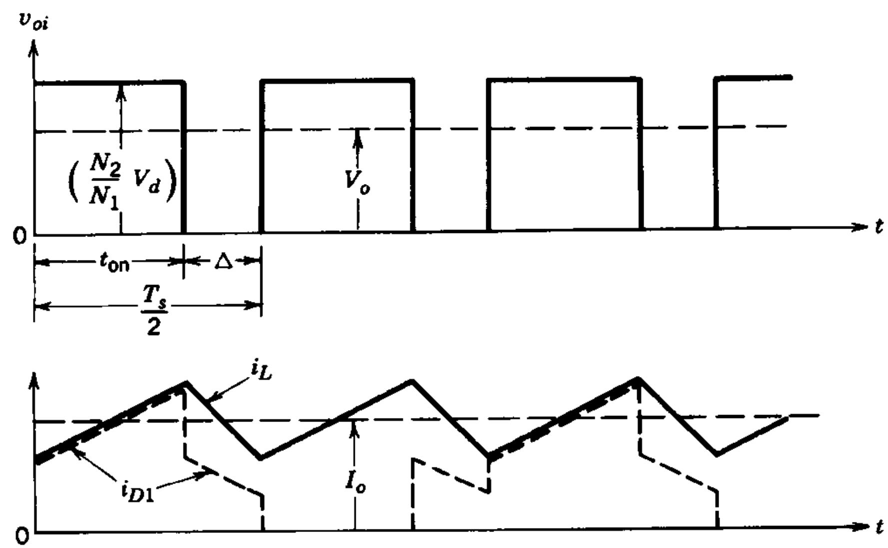



- Two-switch Forward converter is very commonly used

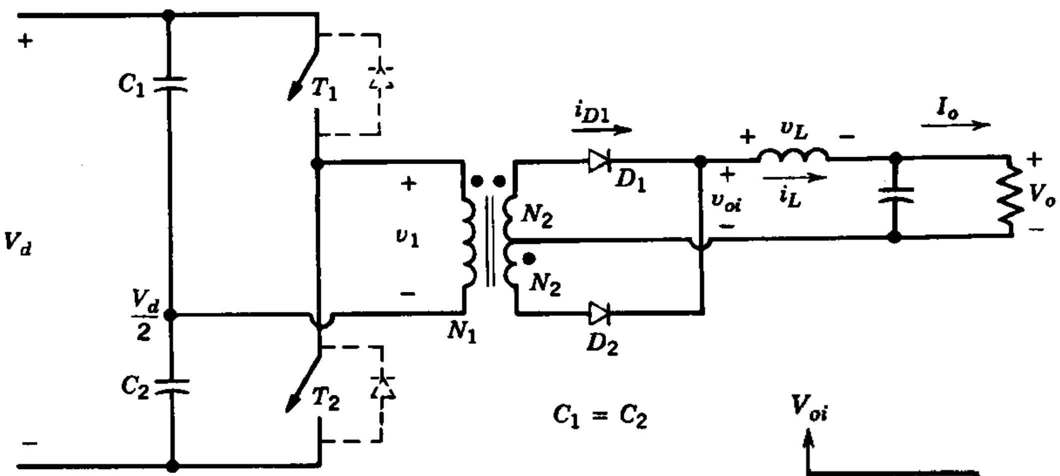
# Push-Pull Inverter

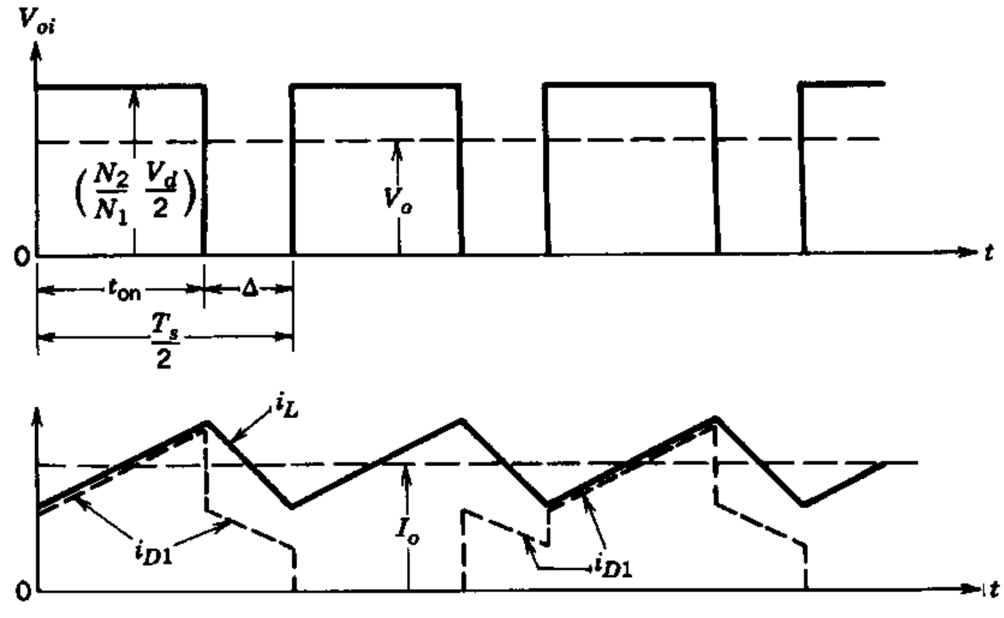



- Leakage inductances become a problem

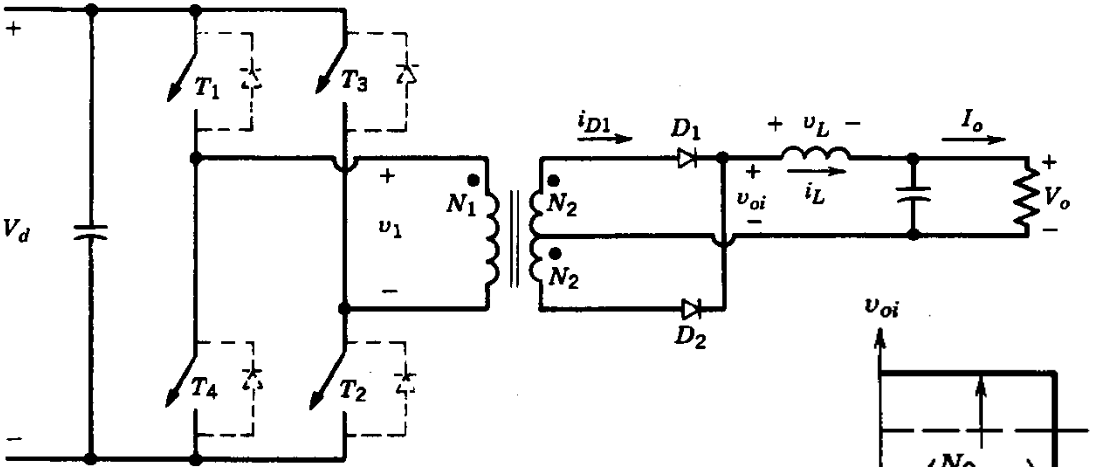
# Half-Bridge Converter

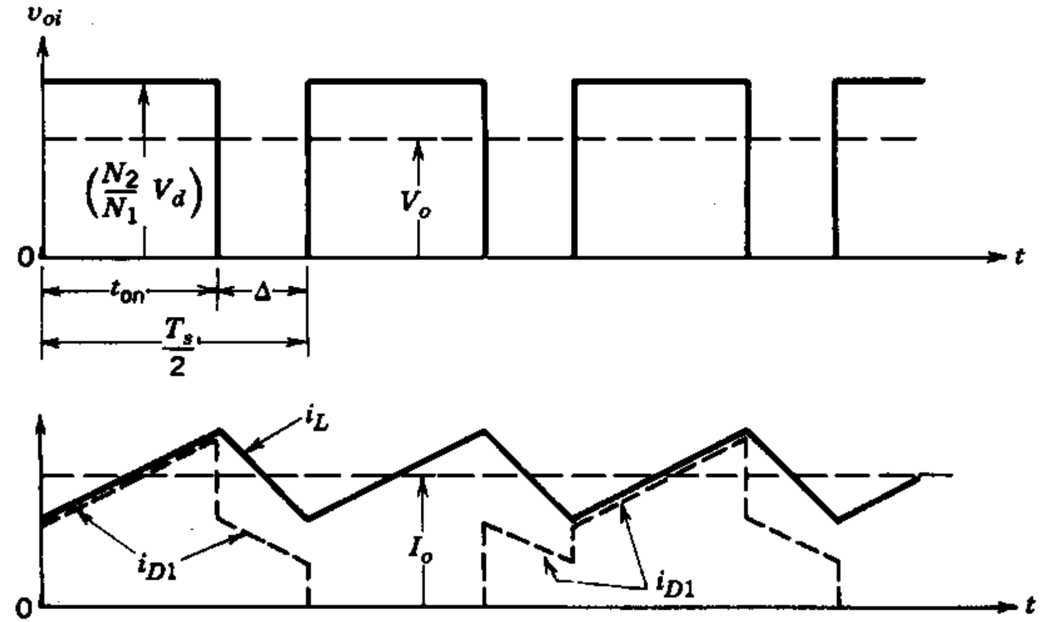



- Derived from Buck

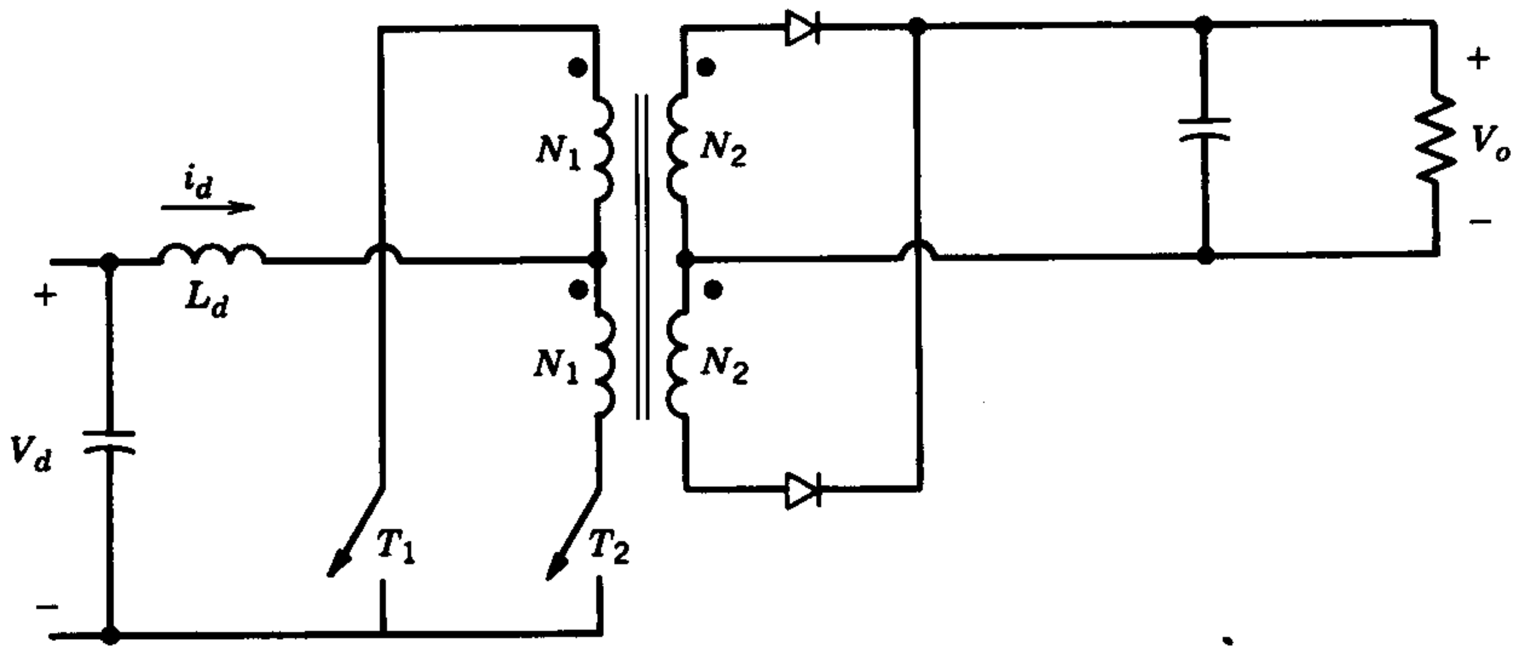
# Full-Bridge Converter



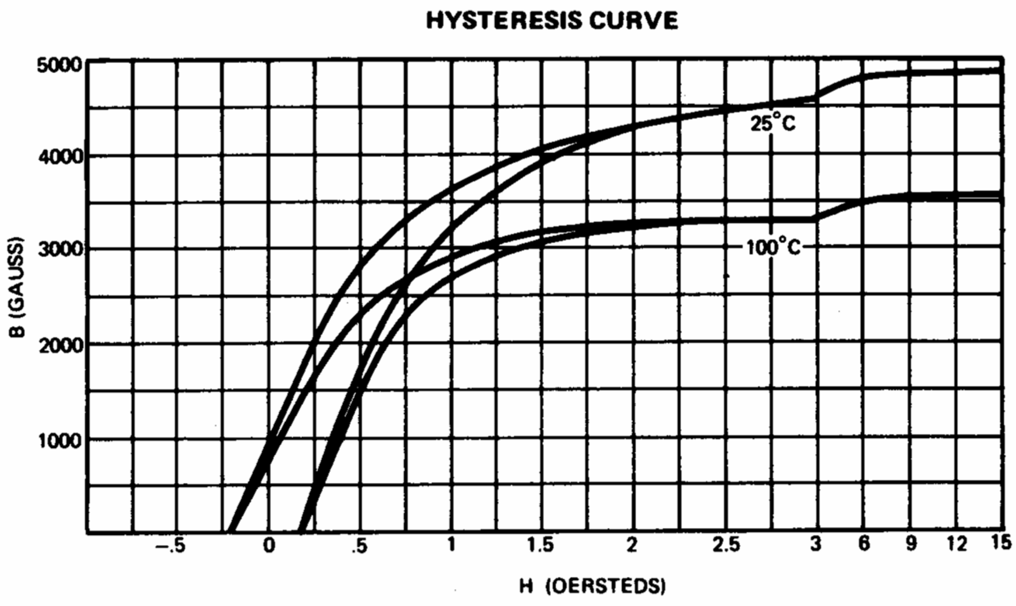

- Used at higher power levels (> 0.5 *kW* )

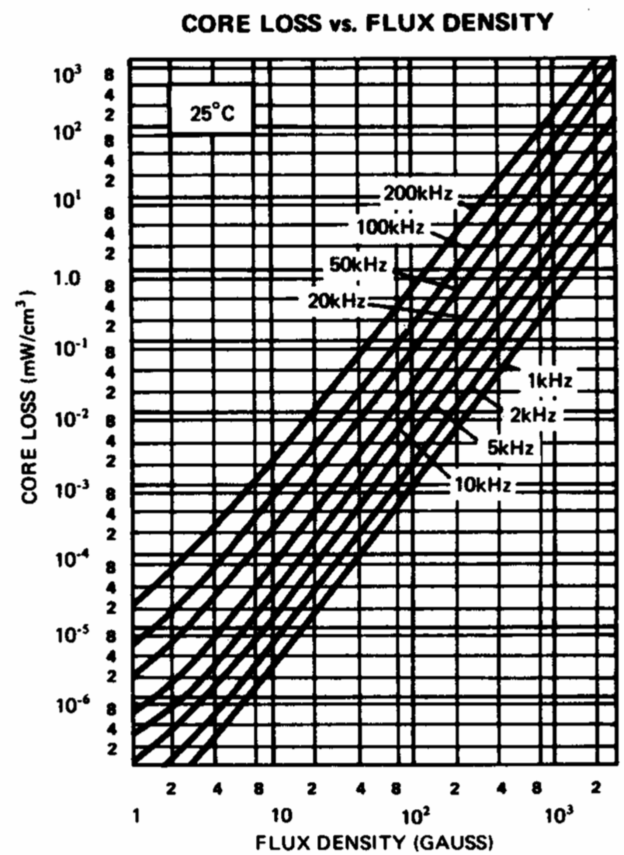
# Current-Source Converter




- More rugged (no shoot-through)
  but both switches must not be open simultaneously

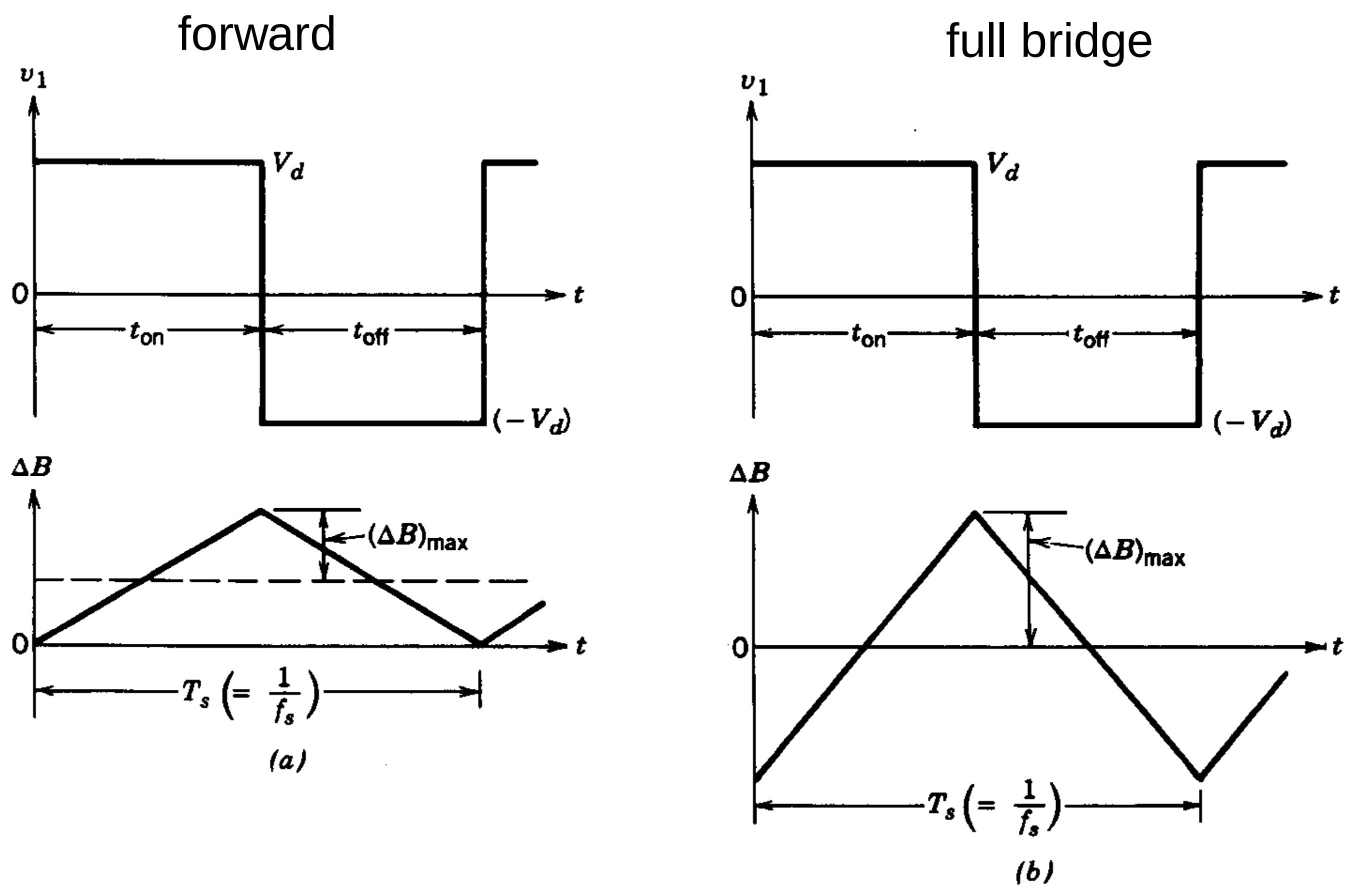
# Ferrite Core Material



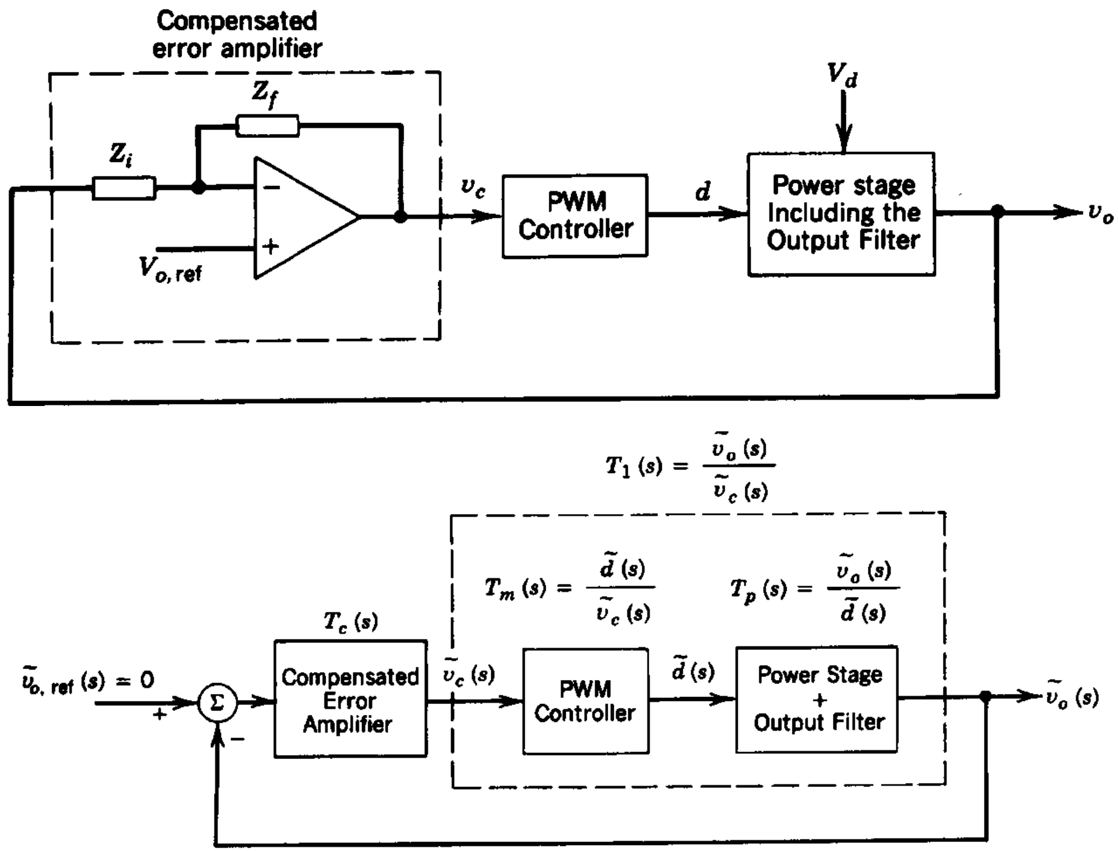

- Several materials to choose from based on applications

# Core Utilization in Various Converter Topologies



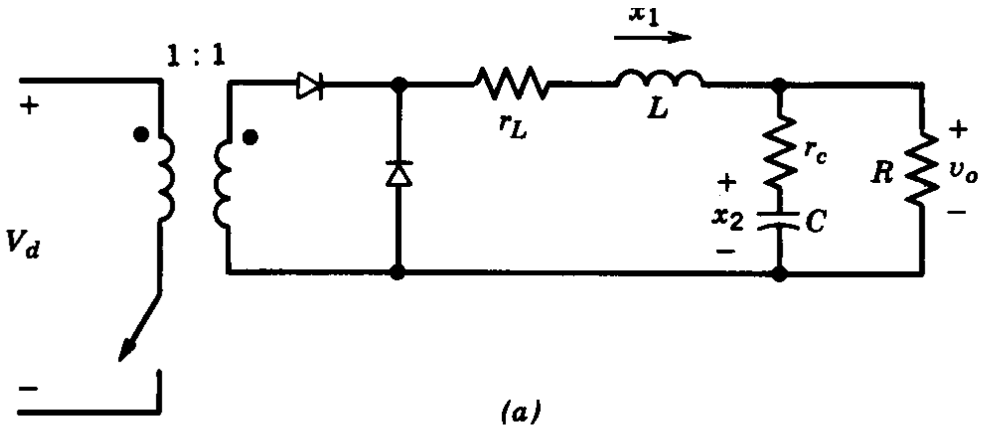

- At high switching frequencies, core losses limit excursion of flux density

# Control to Regulate Voltage Output



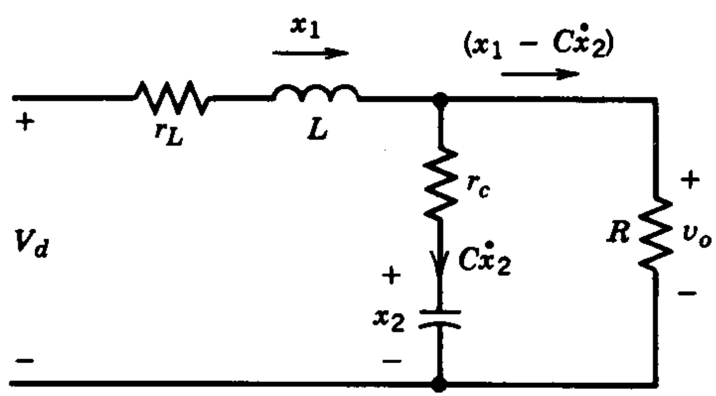

- Linearized representation of the feedback control system

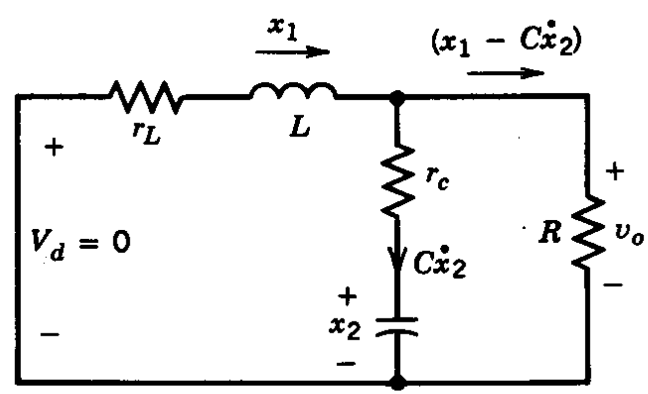
# Forward Converter – An Example




(a)

$V_d$ = 8 V
$V_o$ = 5 V
$r_L$ = 20 mΩ
$L$ = 5 μH
$r_c$ = 10 mΩ
$C$ = 2,000 μF
$R$ = 200 mΩ
$f_s$ = 200 kHz

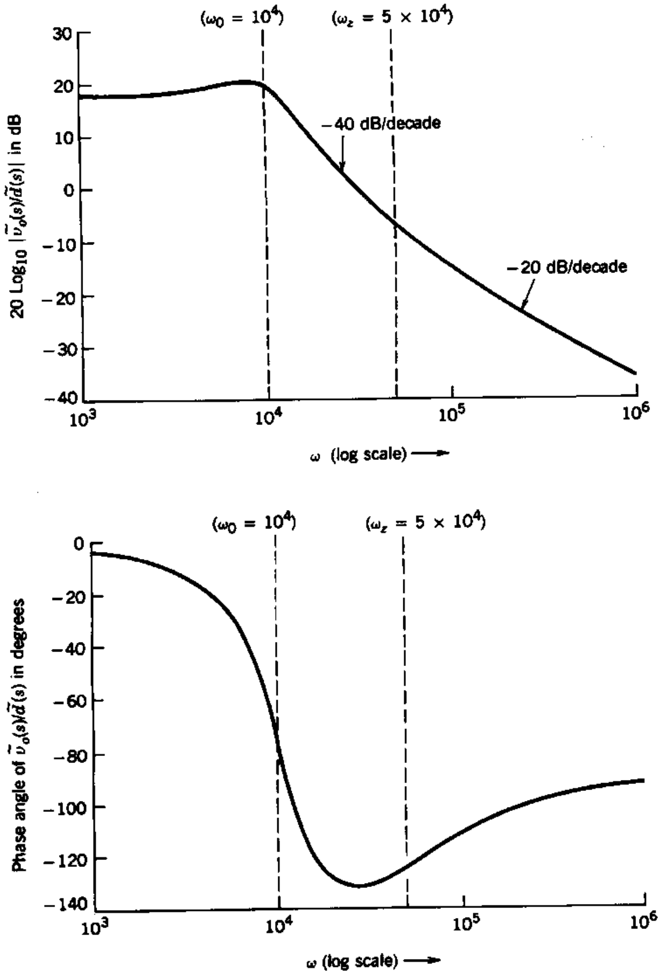


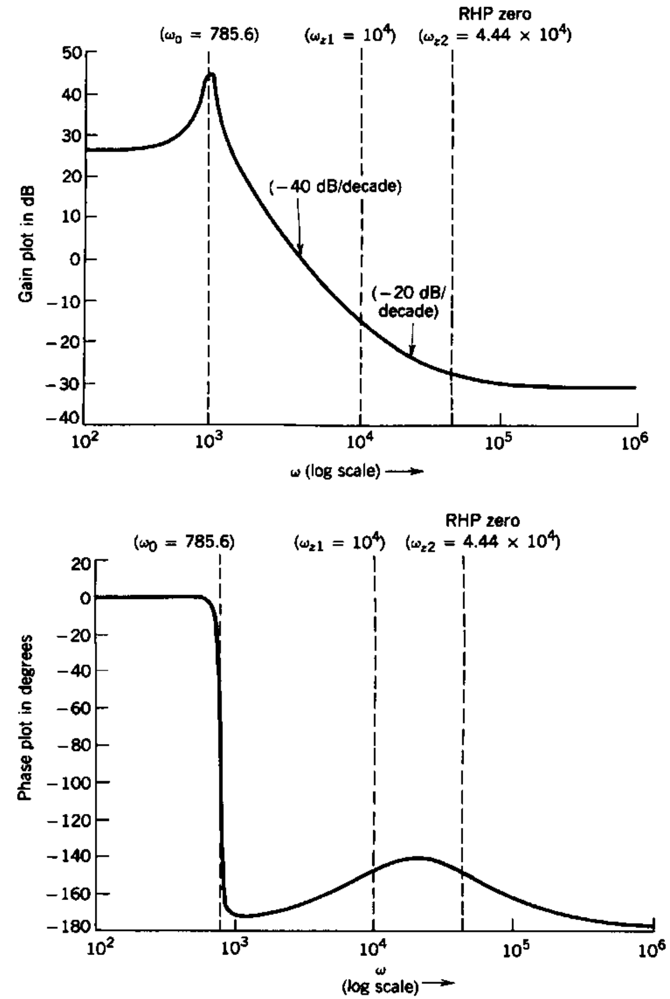

- The switch and the diode are assumed to be ideal

# Transfer Function Plots

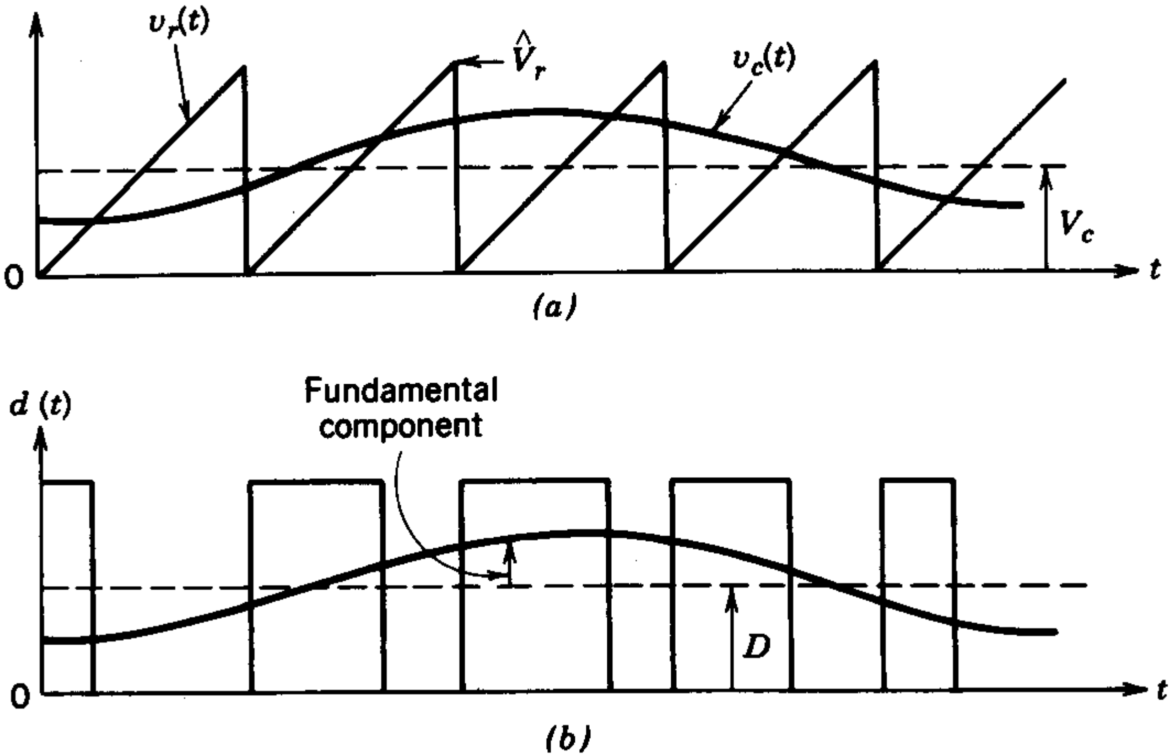
- Forward converter

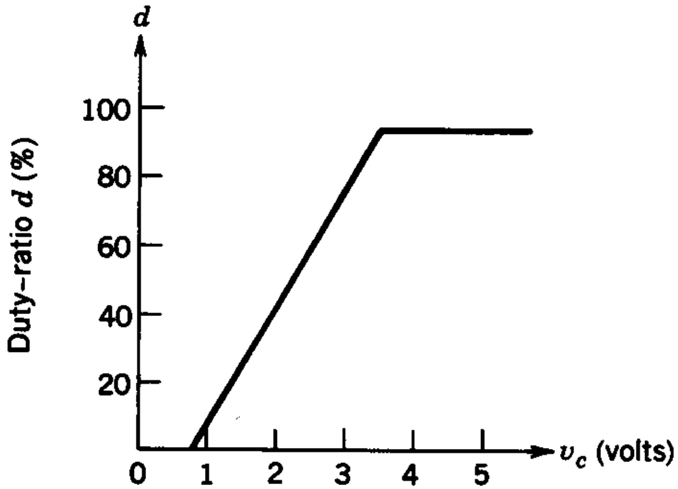



- Flyback converter



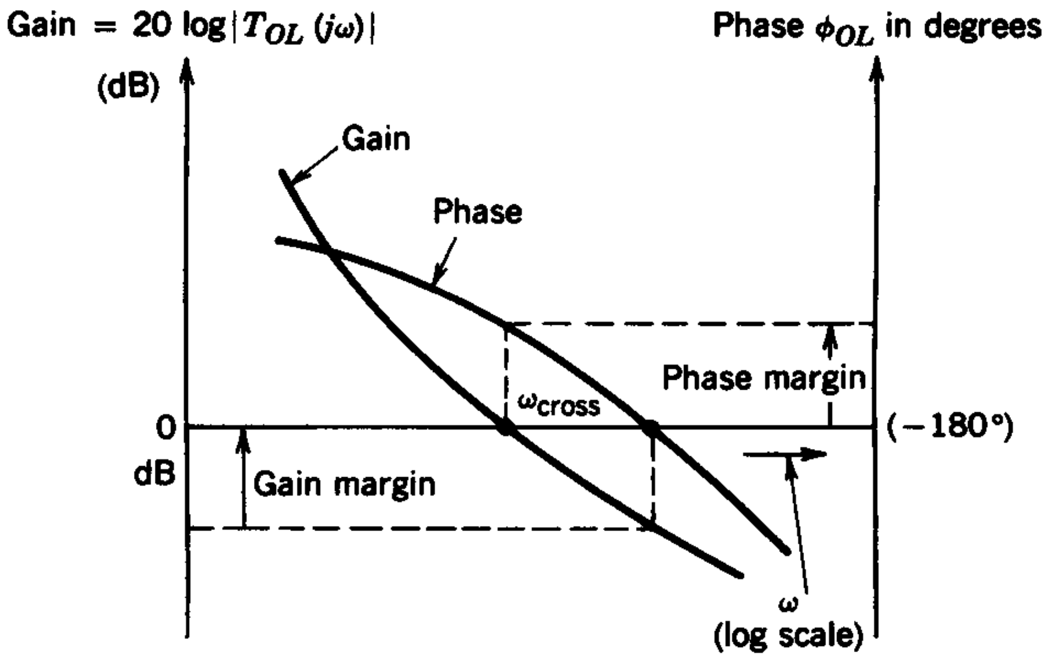
# Linearizing the PWM Block



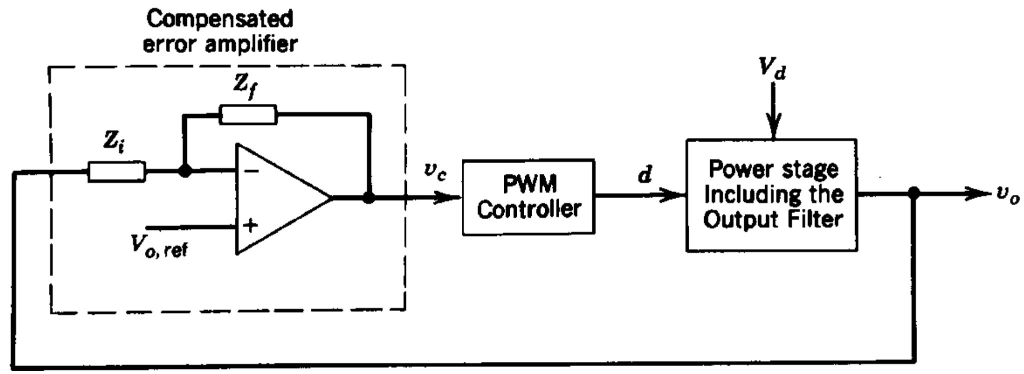

- The transfer function is essentially a constant with zero phase shift

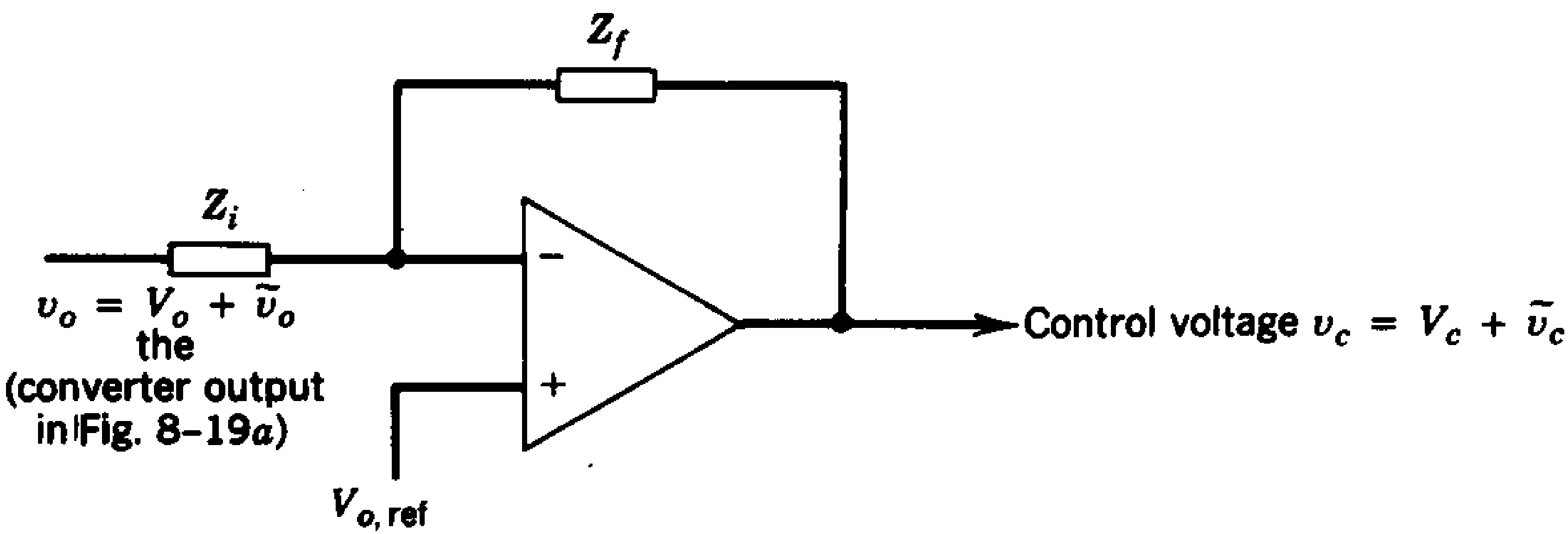
# Typical Gain and Phase Plots of the Open-Loop Transfer Function




- Definitions of the crossover frequency, phase and gain margins???

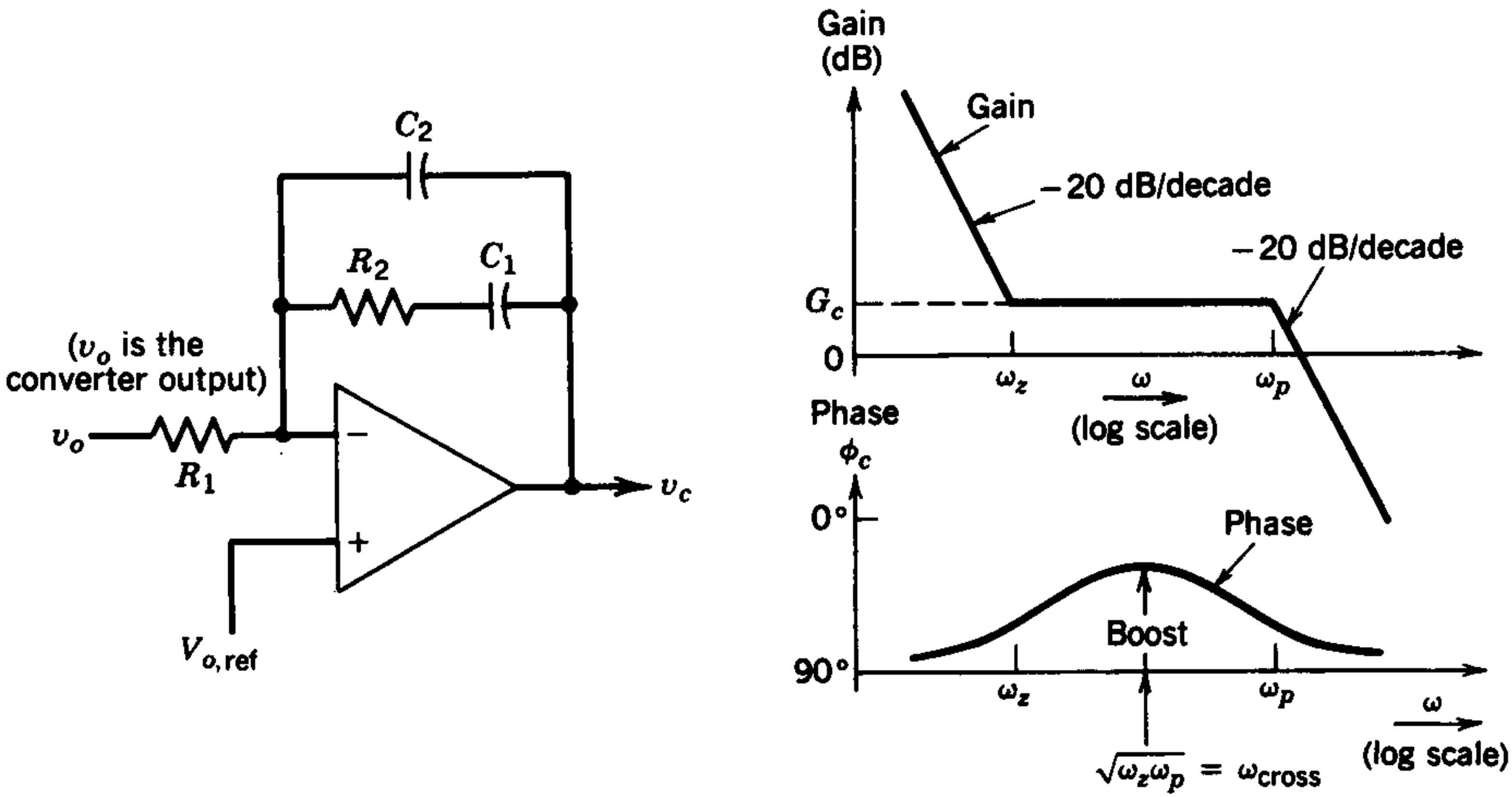
# A General Amplifier for Error Compensation



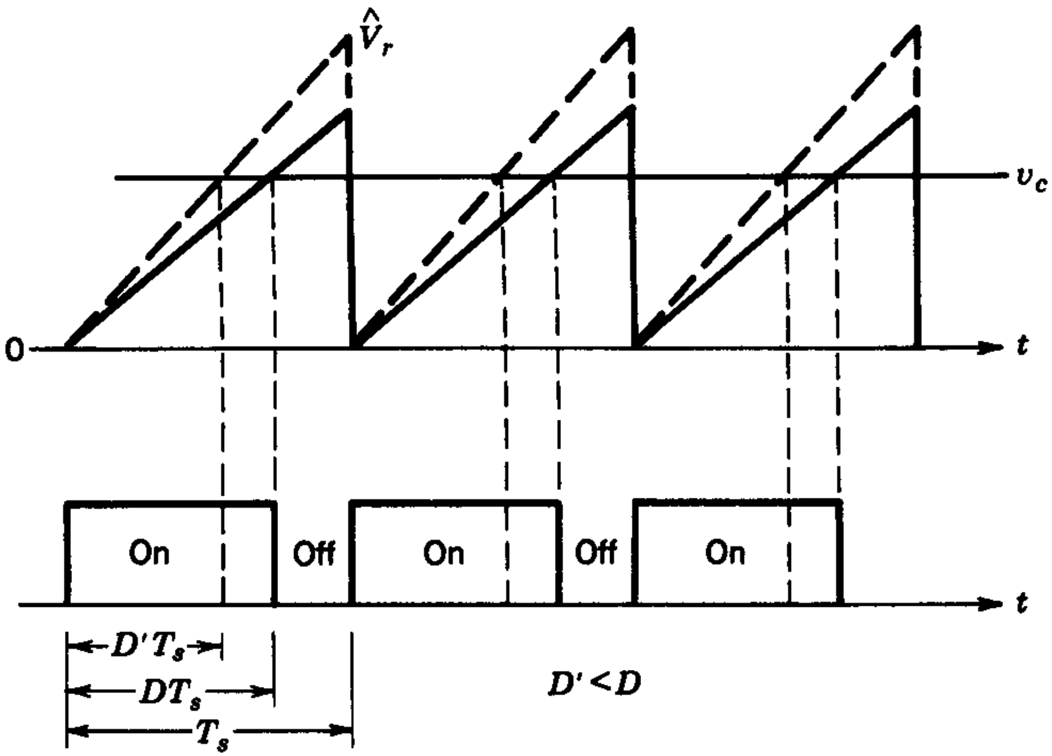

- Can be implemented using a single op-amp

# Real type of error amplifier



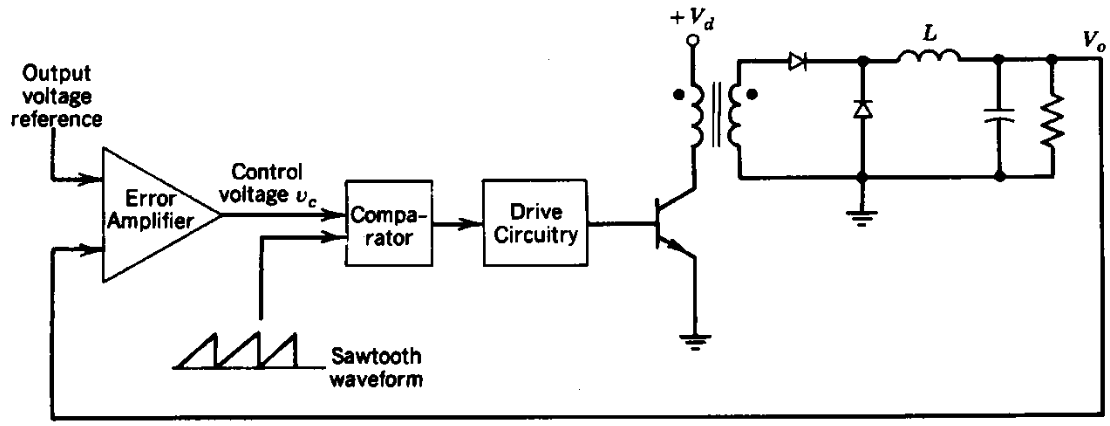

- Shows phase boost at the crossover frequency

# Voltage Feed-Forward
# (when input voltage changes)

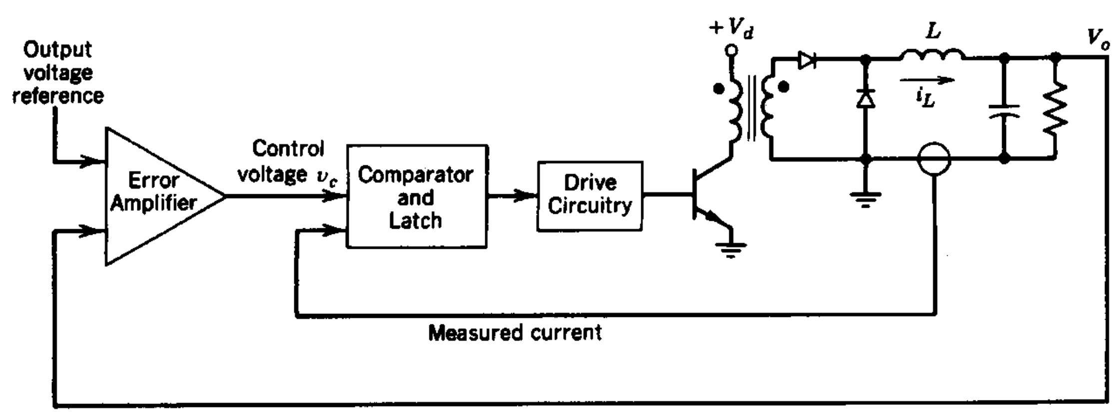



- Makes converter immune from input voltage variations

# Voltage versus Current Mode Control



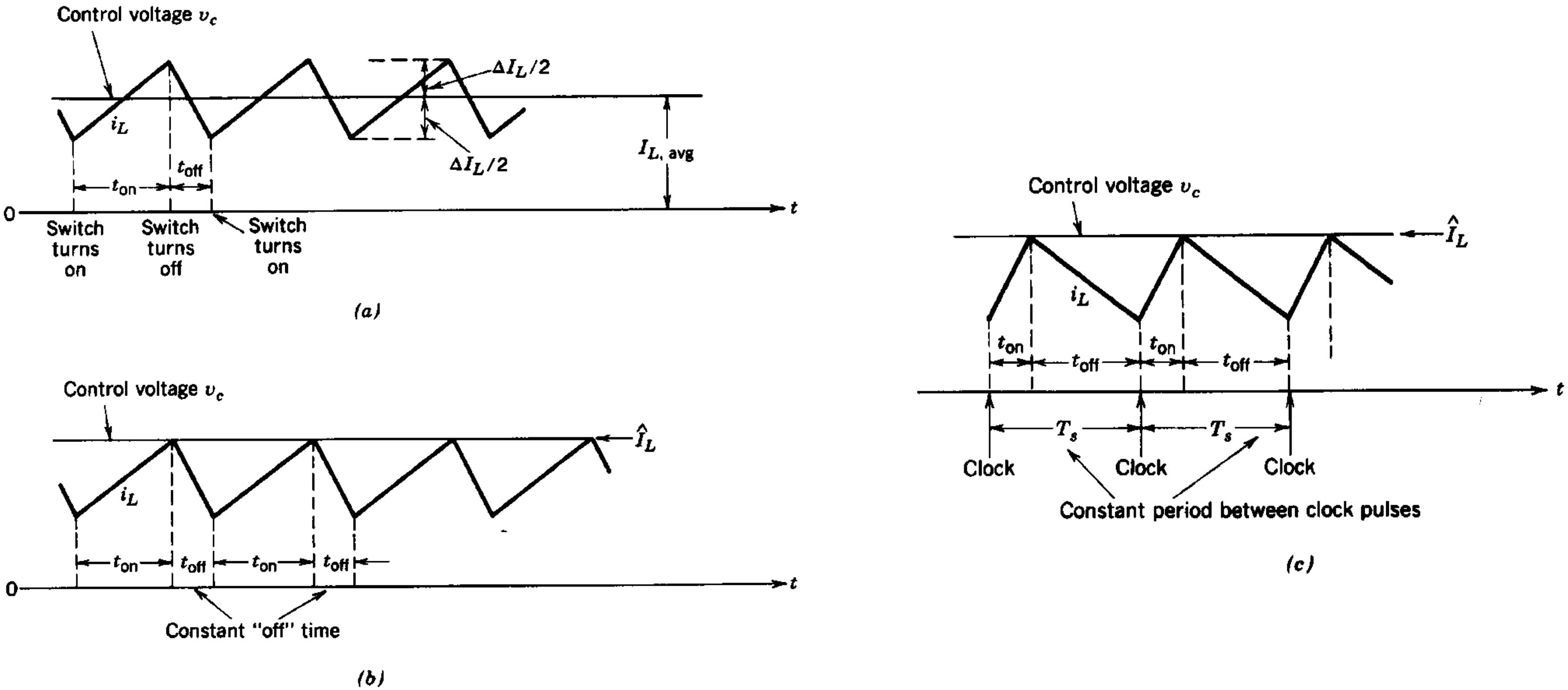

(a)




(b)

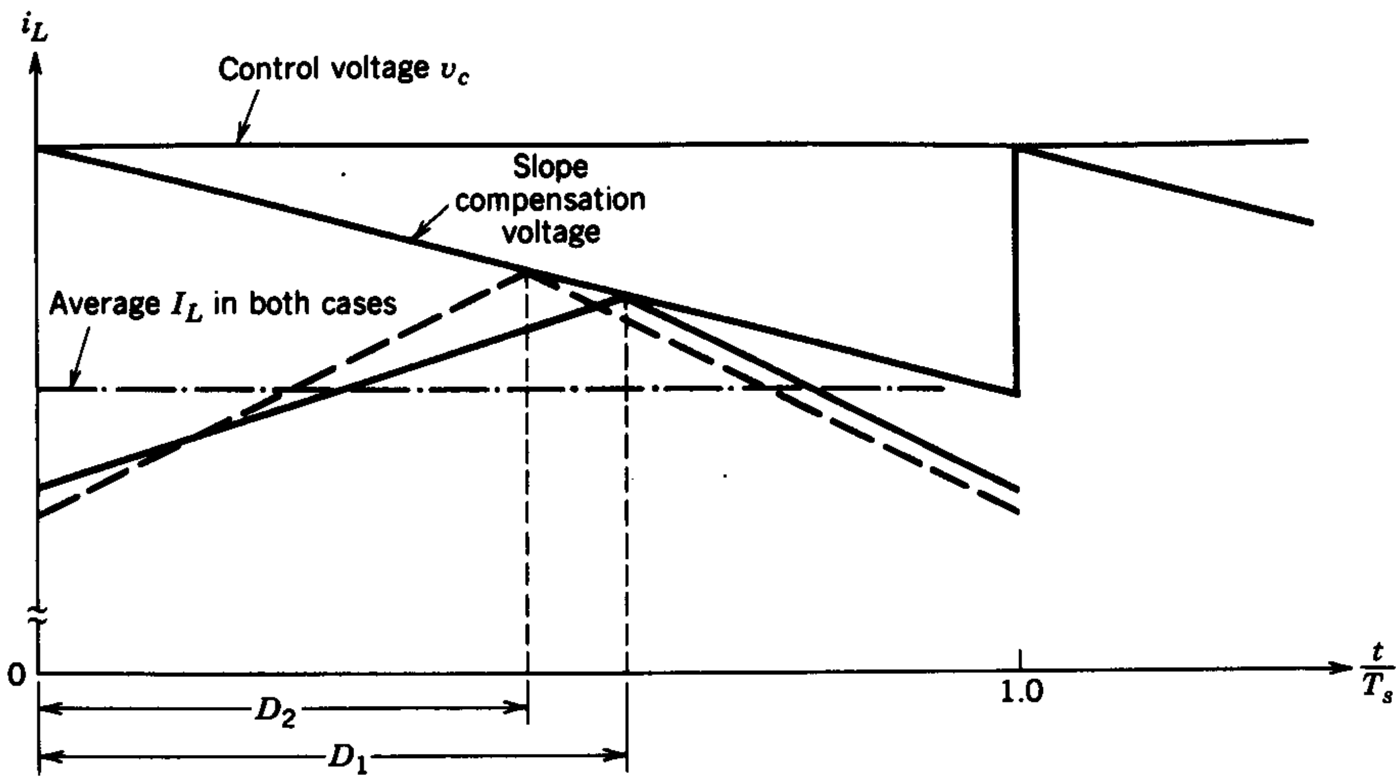
- Regulating the output voltage is the objective in both modes of control

# Various Types of Current Mode Control




- a – tolerance band control, b – constant-off-time control, c – constatnt frequency with turn-on at clock time
- **Constant frequency, peak-current mode control is used most frequently**

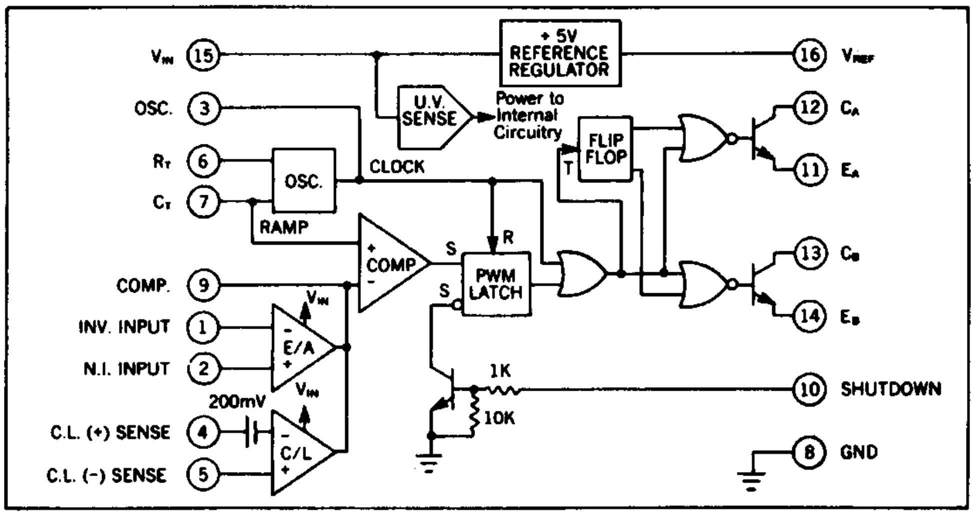
# Peak Current Mode Control

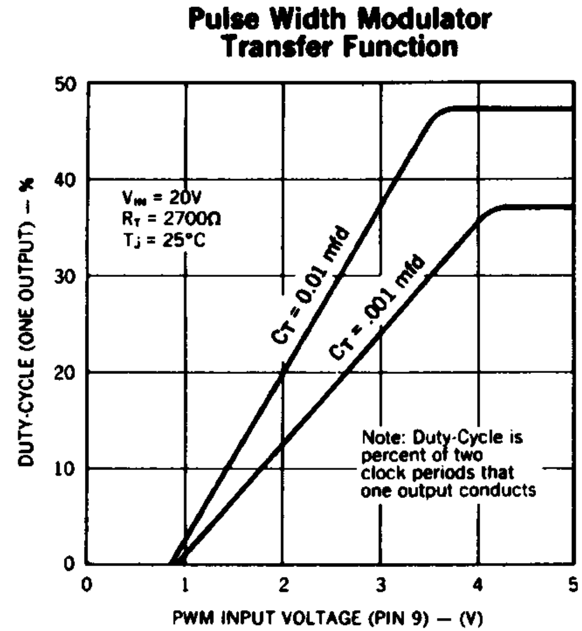



- Slope compensation is needed

# A Typical PWM Control IC

BLOCK DIAGRAM

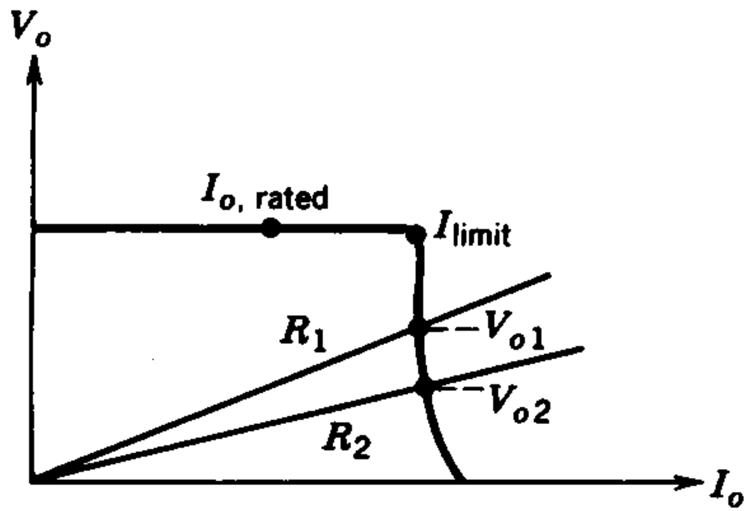


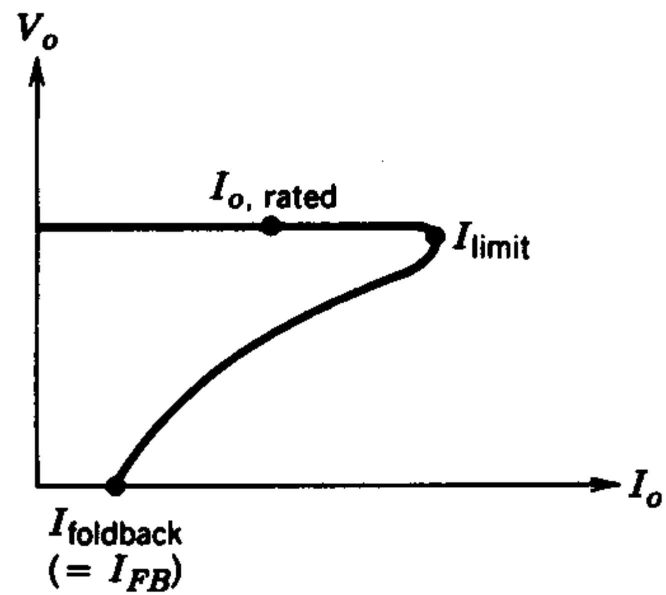

- Many safety control functions are built in

# Current Limiting

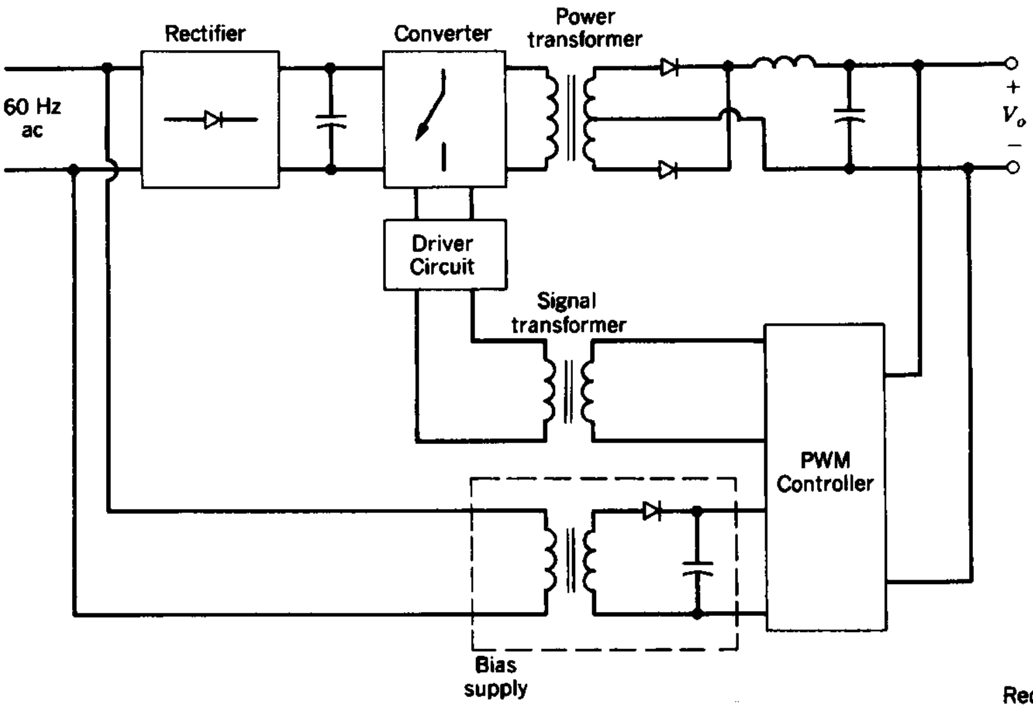
- Constant current limiting
- Foldback current limiting

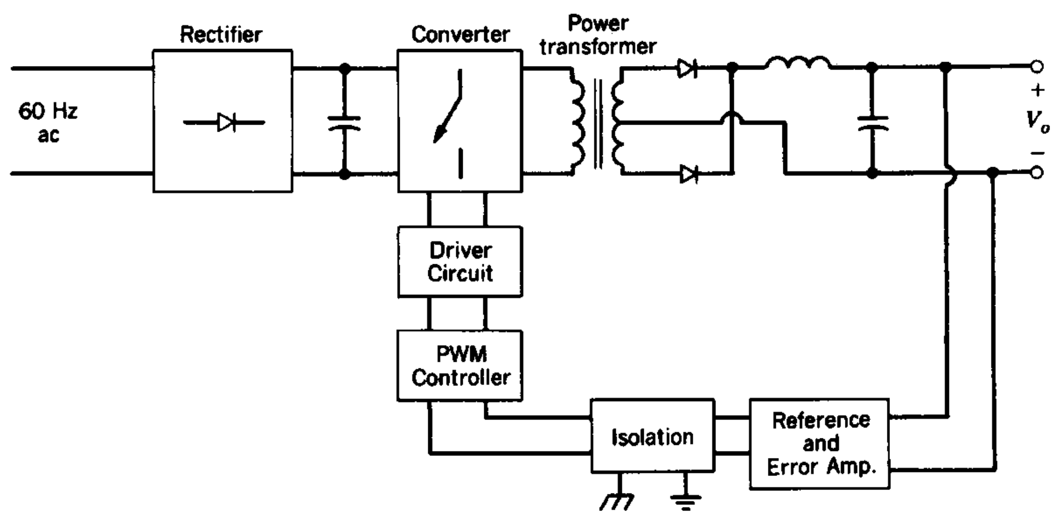



(a)

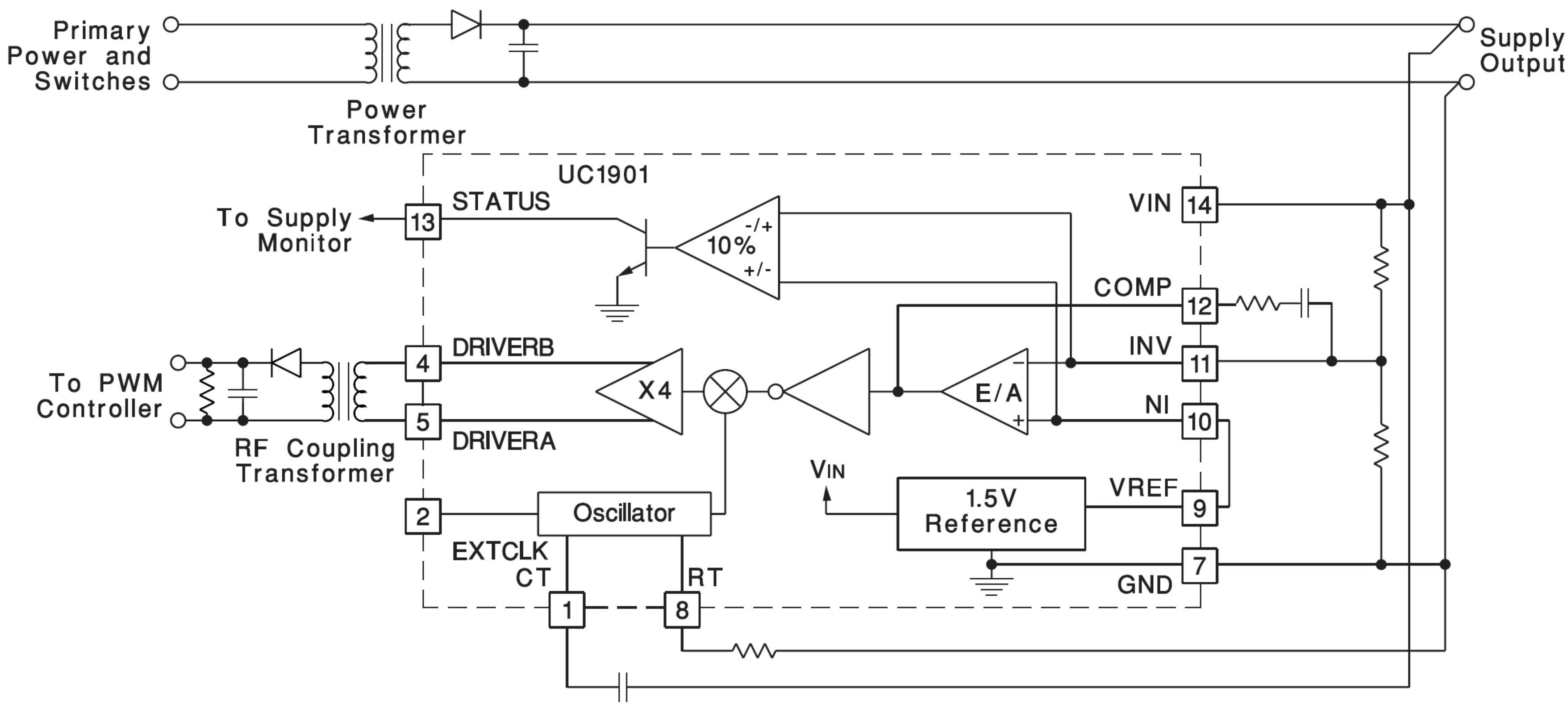


# Implementing Electrical Isolation in the Feedback Loop

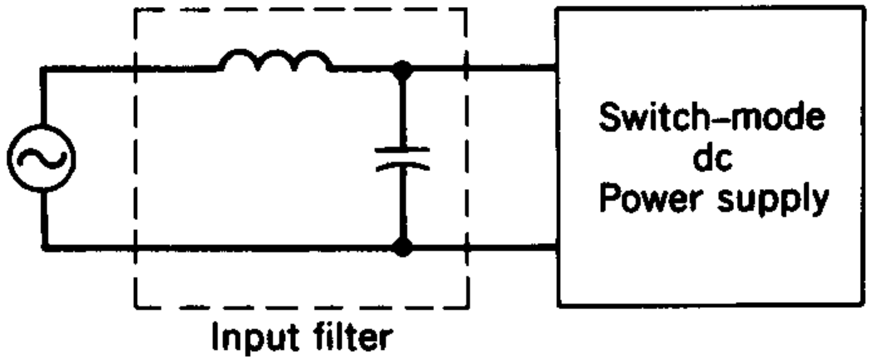


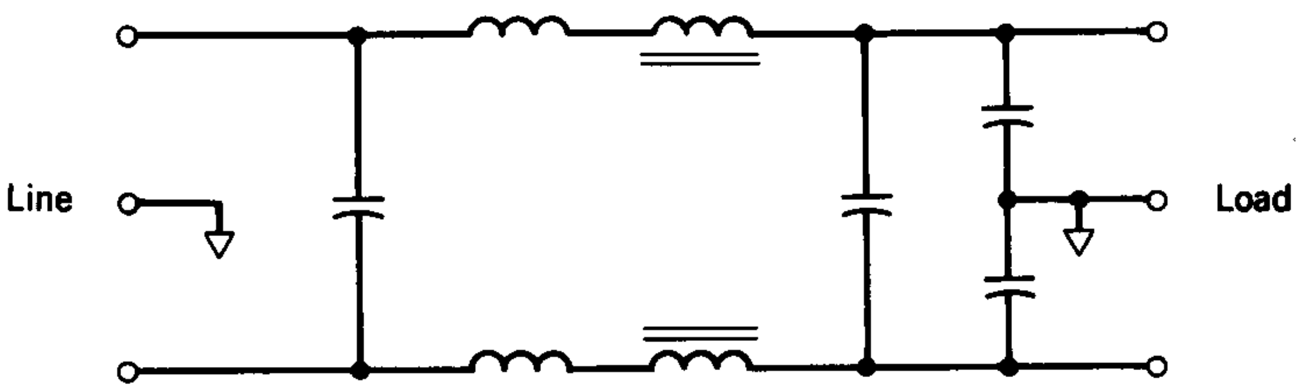



# Implementing Electrical Isolation in the Feedback Loop – practical approach UC1901



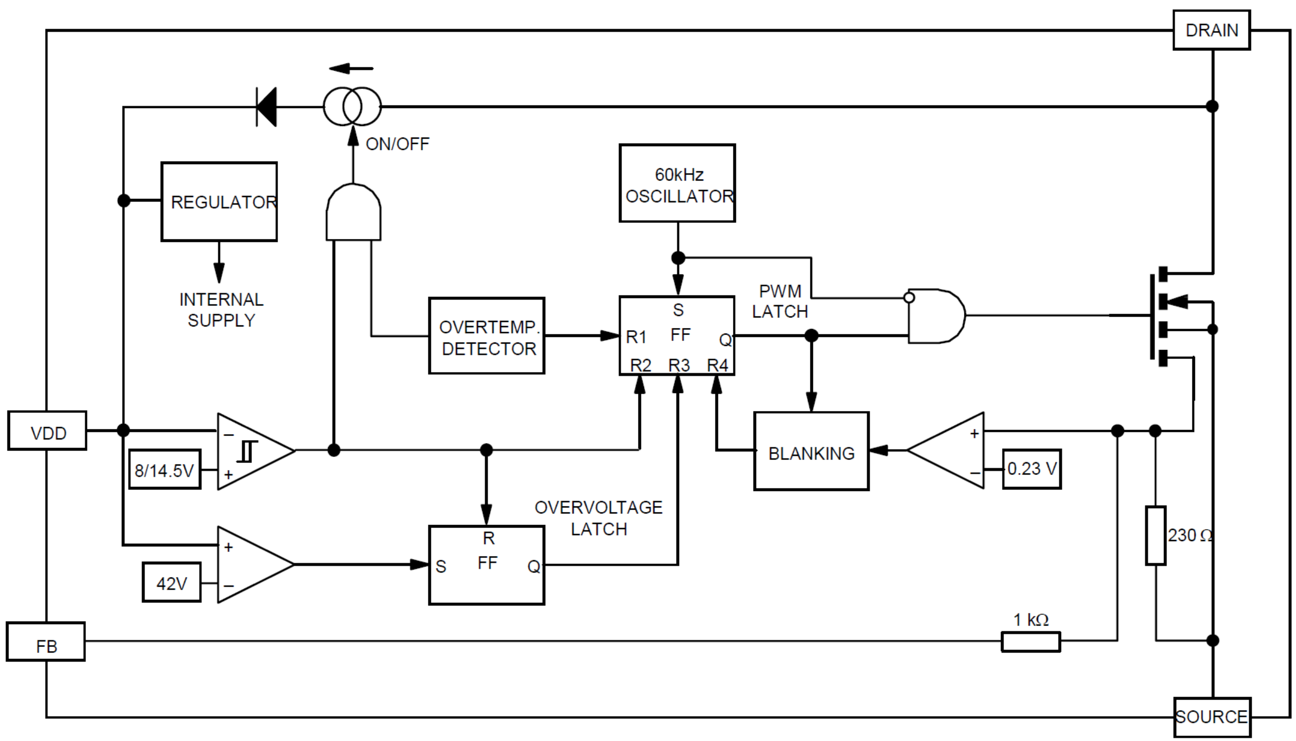
# Input Filter



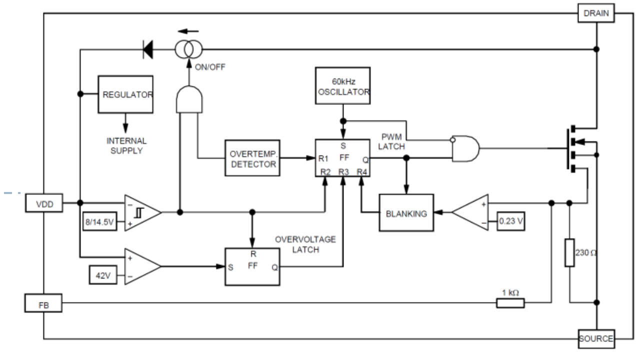



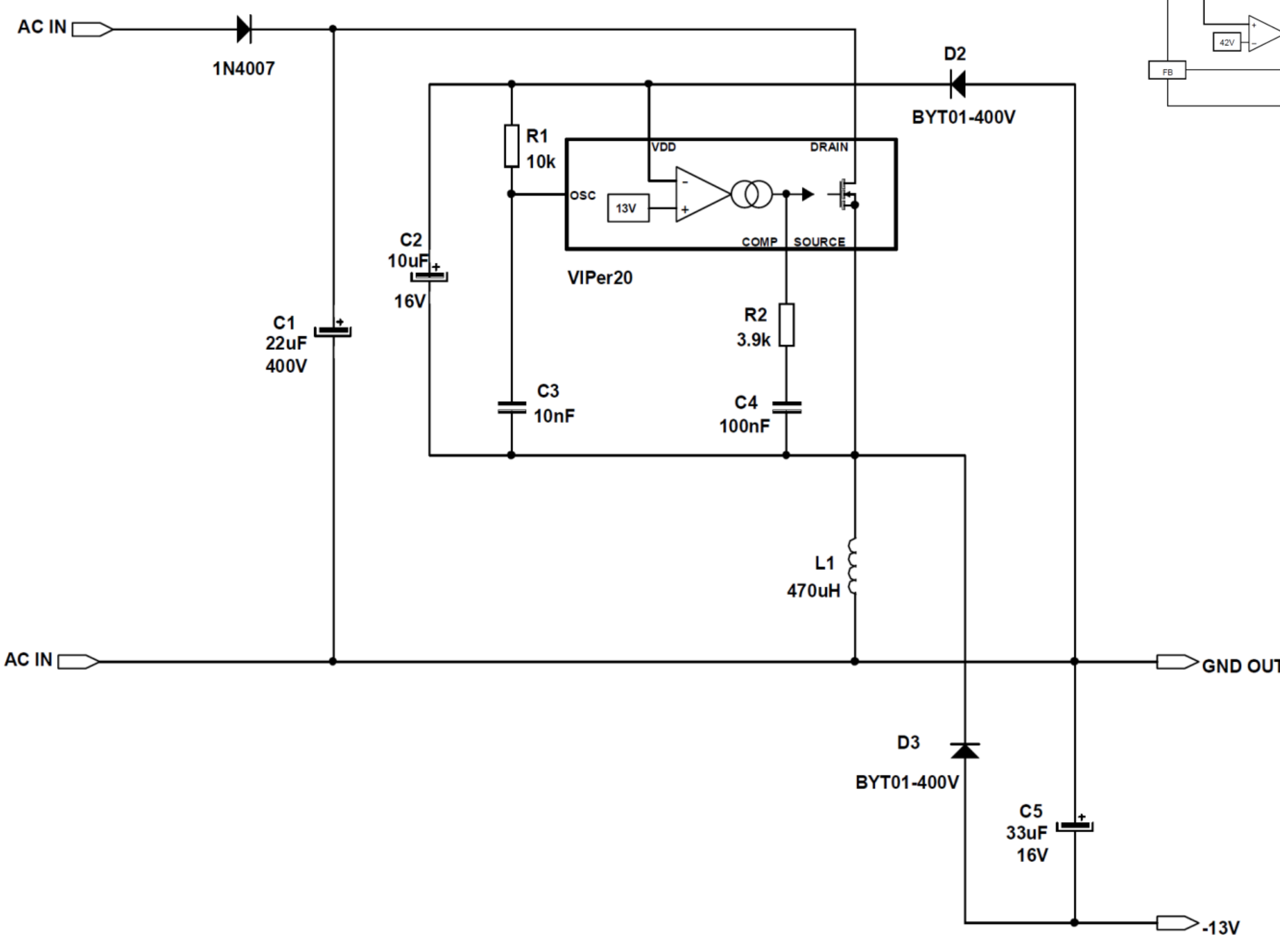

- Needed to comply with the EMI and harmonic limits

# Viper22
# fixed frequency off-line converter

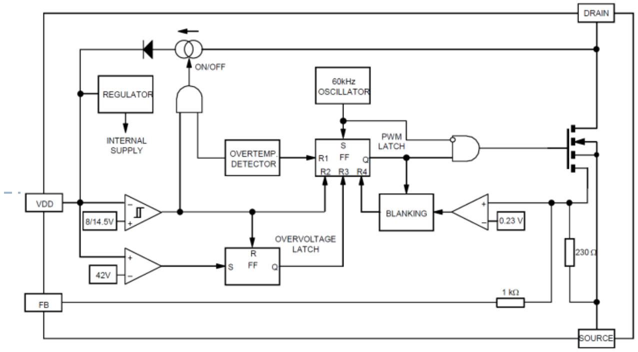


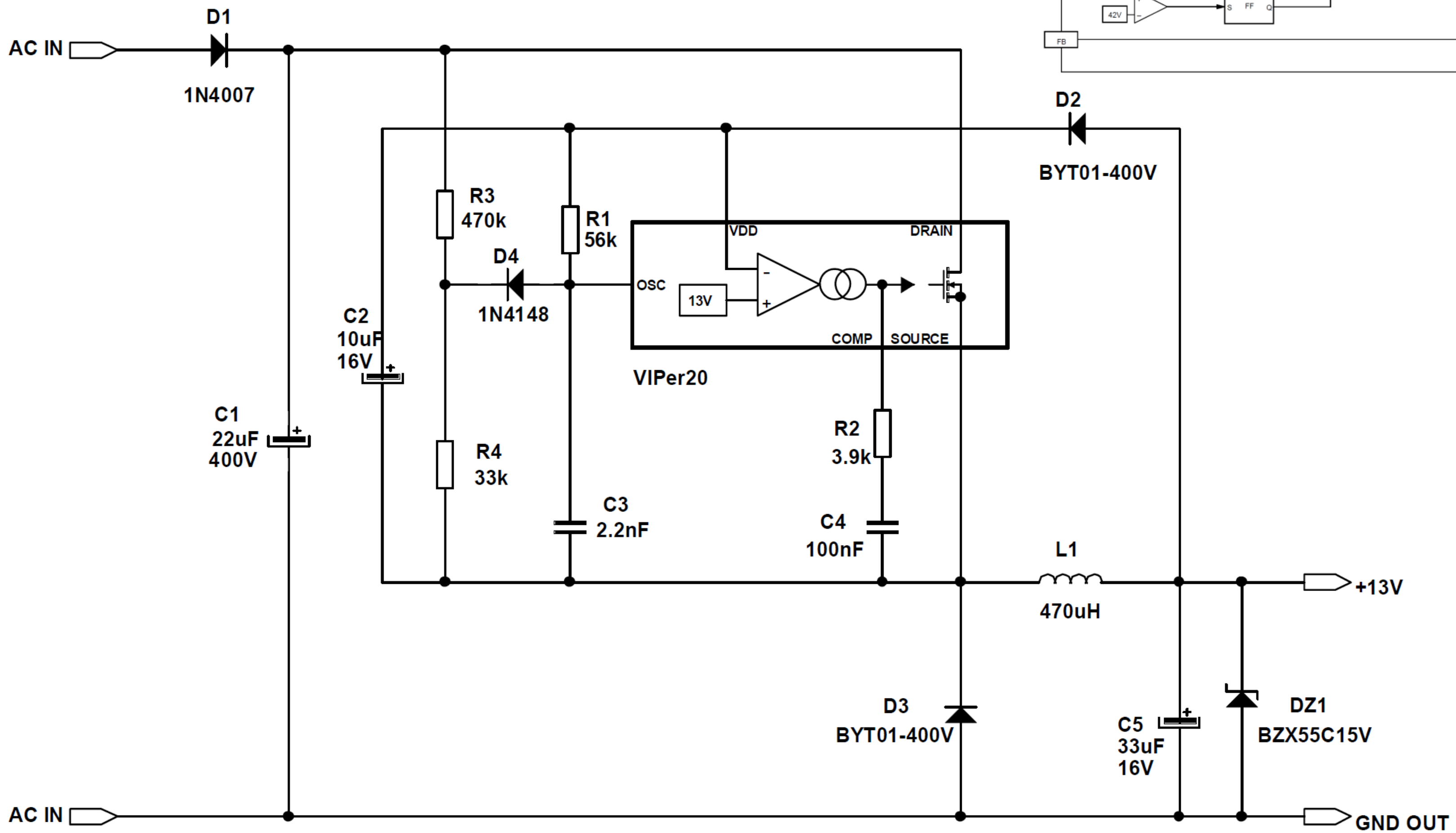
# Viper simple nonisolated



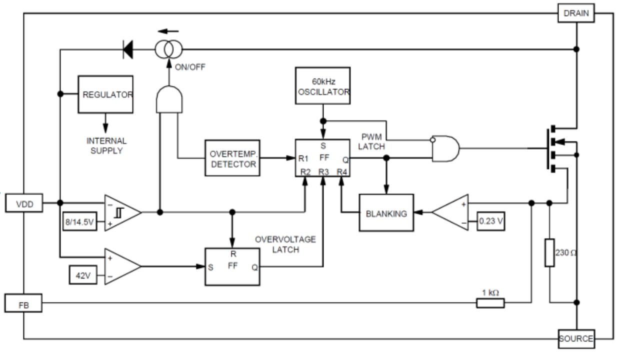



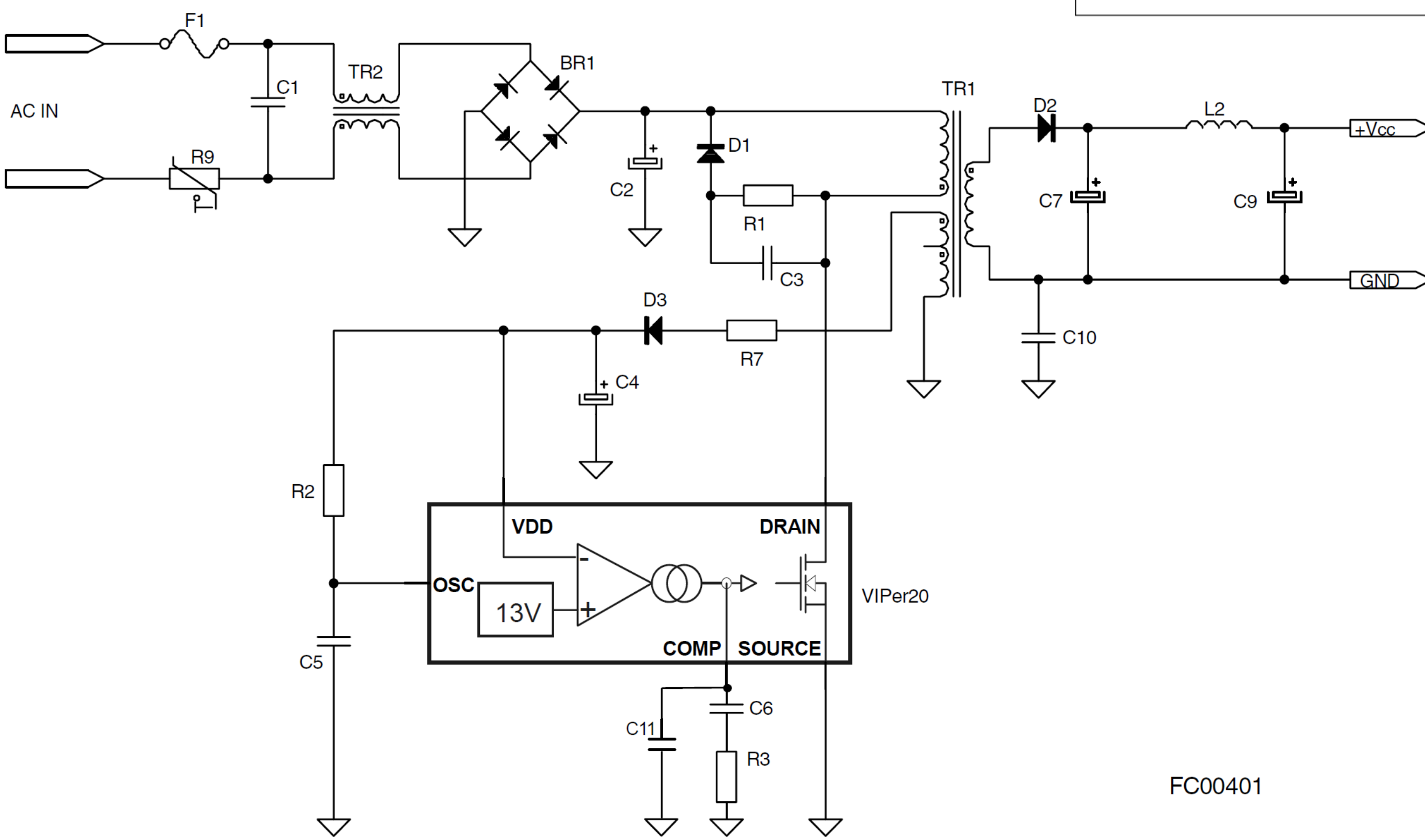
# Viper simple nonisolated



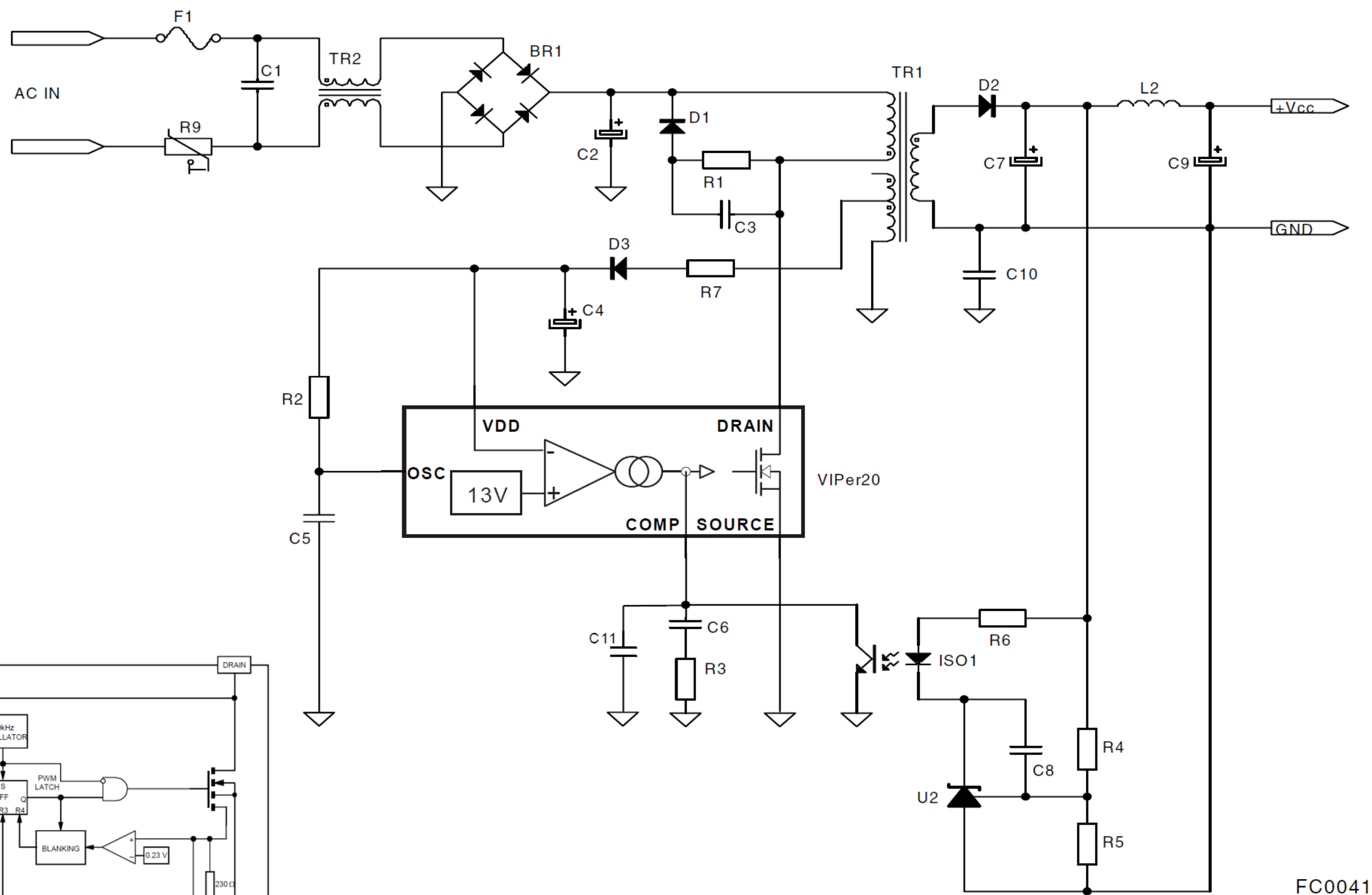



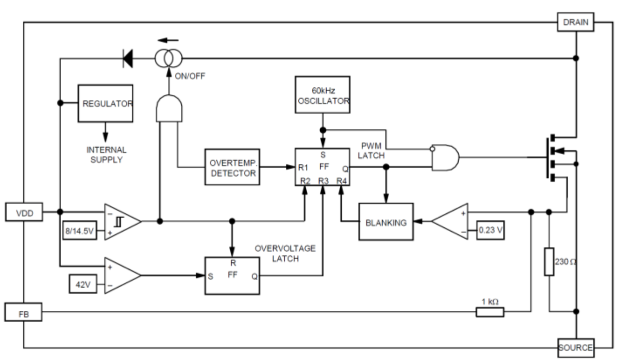
# Viper simple



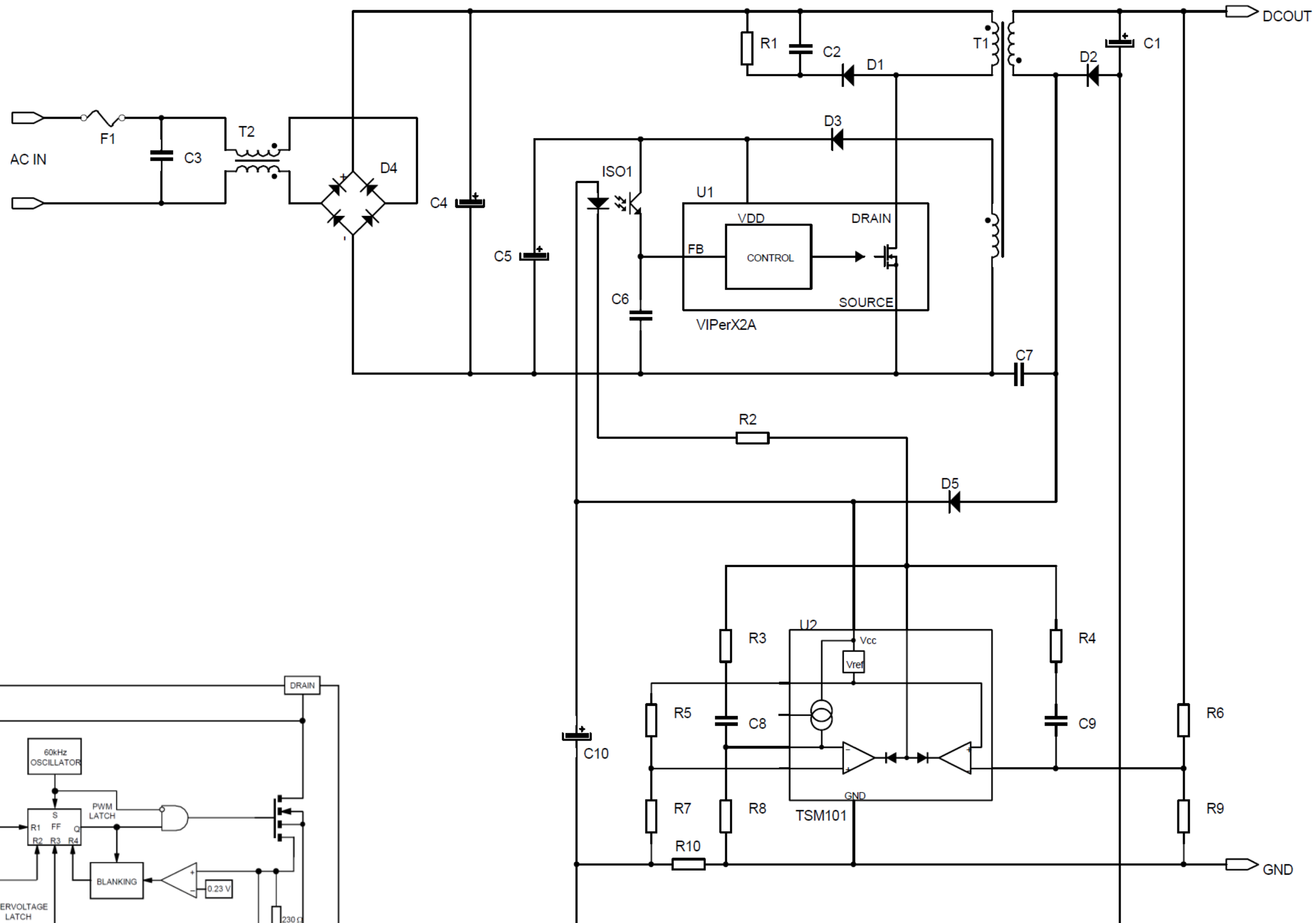



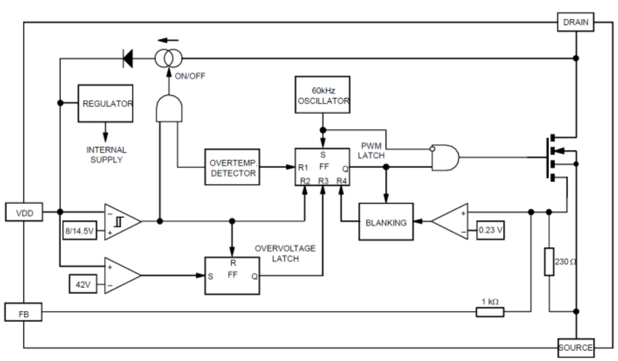
# Viper with optocoupler feedback



# Viper battery charger

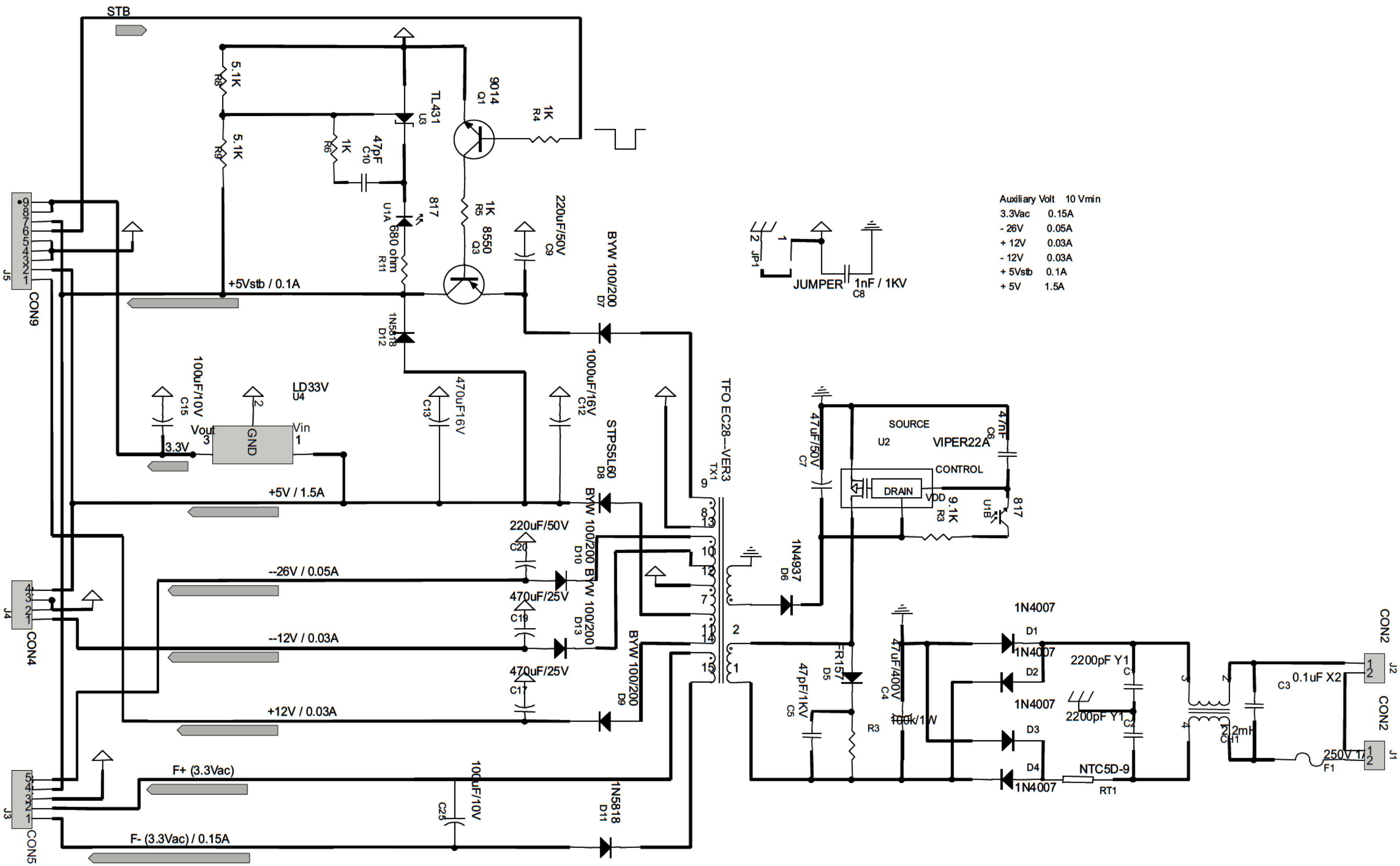


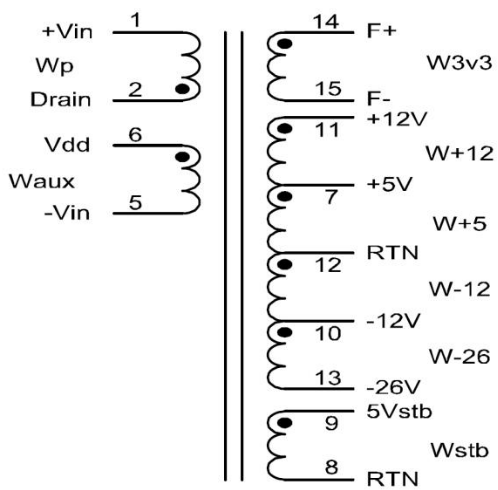
# Viper
# low-cost universal DVD supply

| Input | Output 1 | Output 2 | Output 3 | Output 4 | Output 5 | Output 6 |
|---|---|---|---|---|---|---|
| Universal line | 5 V+/-5% (1) | +12 V+/-5% (1) | -12 V+/-5% (1) | -26 V+/-5% (1) | 3.3 V+/-5% (1) | 5 $V_{stb}$+/-5% (1) |
| Min. 85 $V_{ac}$ Max. 265 $V_{ac}$ | Imin. 20 mA Imax.1.5 A | Imax. 30 mA | Imax. 30 mA | Imax.50 mA | Imax. 150 mA | Imax.100 mA |

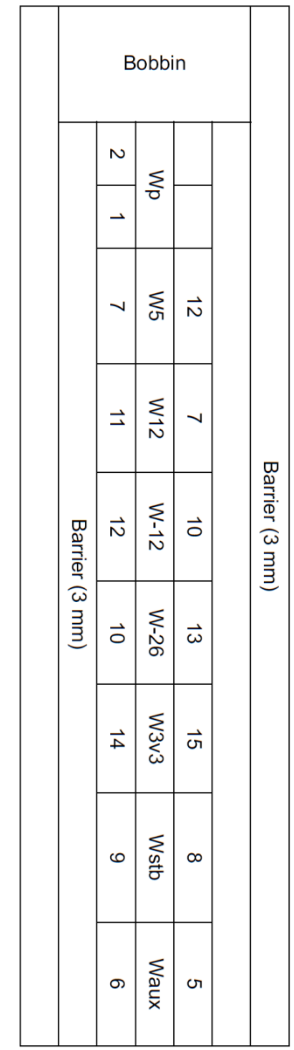
# Viper
# low-cost universal DVD supply



# Viper low-cost universal DVD supply – transformer

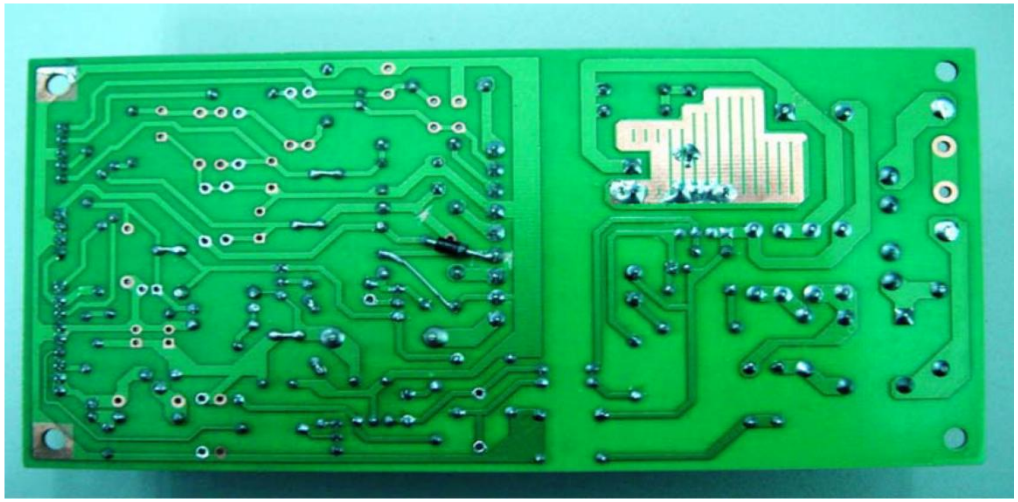


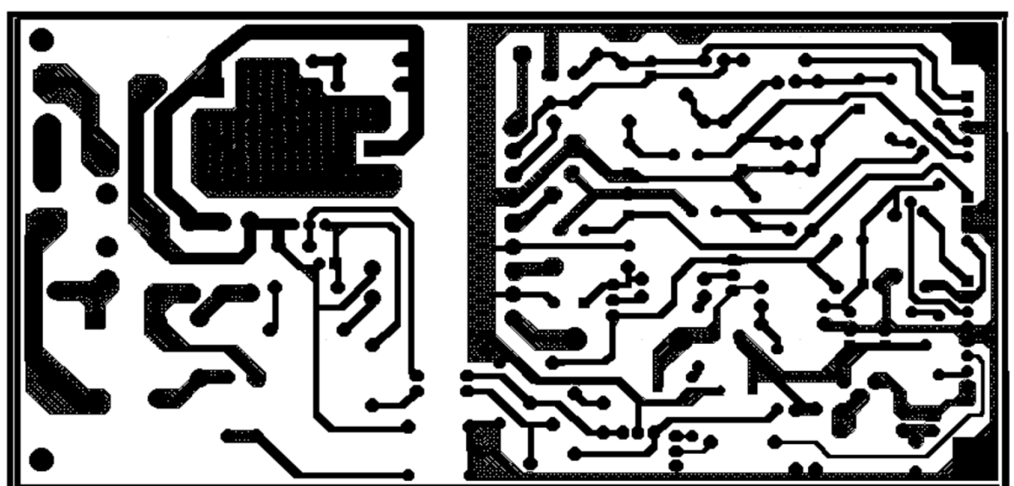

**Primary inductance:** Lp = 2.8 mH 1 kHz, 0.3V
**Leakage inductance:** Lk < 28 uH at secondary and auxiliary winding short (1 kHz, 0.3 V)
**Core:** EER28L
**Bobbin:** ER28 (6 + 9 pin)
**Vendor:** YuanDongDa electronics Co., Ltd




| Layer description | Symbol | Start pin | End pin | Number of layers | Turns | Wire size (mm) |
|---|---|---|---|---|---|---|
| Primary | Wp | Pin 2 | Pin 1 | 2 | 65 | 0.3 |
| Out 1 (5 V/1.5 A) | W5 | Pin 7 | Pin 12 | 1 | 4 | 2*0.6 |
| Out 2 (12 V/0.0 3 A) | W12 | Pin 11 | Pin 7 | 1 | 5 | 0.3 |
| Out 3 (-12 V/0.0 3 A) | W-12 | Pin 12 | Pin 10 | 1 | 9 | 0.45 |
| Out 4 (-26 V/0.05 A) | W-26 | Pin1 0 | Pin 13 | 1 | 10 | 0.3 |
| Out 5 (5 $V_{stb}$/0. 1 A) | Wstb | Pin 9 | Pin 8 | 1 | 12 | 0.3 |
| Out 6 (3. 3V/0.15 A) | W3v3 | Pin 14 | Pin 15 | 1 | 3 | 0.3 |
| Auxiliary | Waux | Pin 6 | Pin 5 | 1 | 24 | 0.3 |

# Viper low-cost universal DVD supply – PCB layout





# Homework

- Przeanalizwoać aplikacje
  - TOP221
  - MC33369