



Analog Electronics

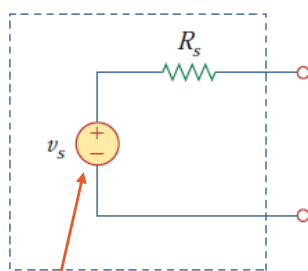
Lecture #6

Б. Бат-Отгон © 2013 Улаанбаатар

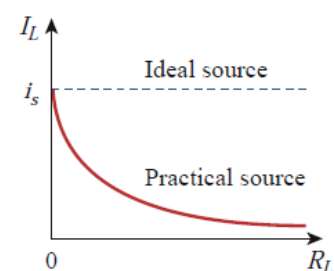
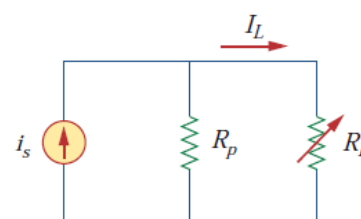
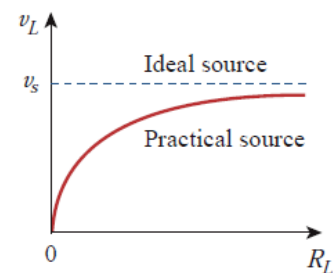
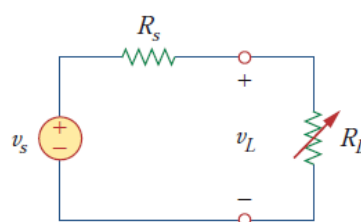
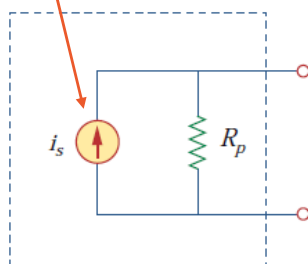
Switching Power Supply

Le.11

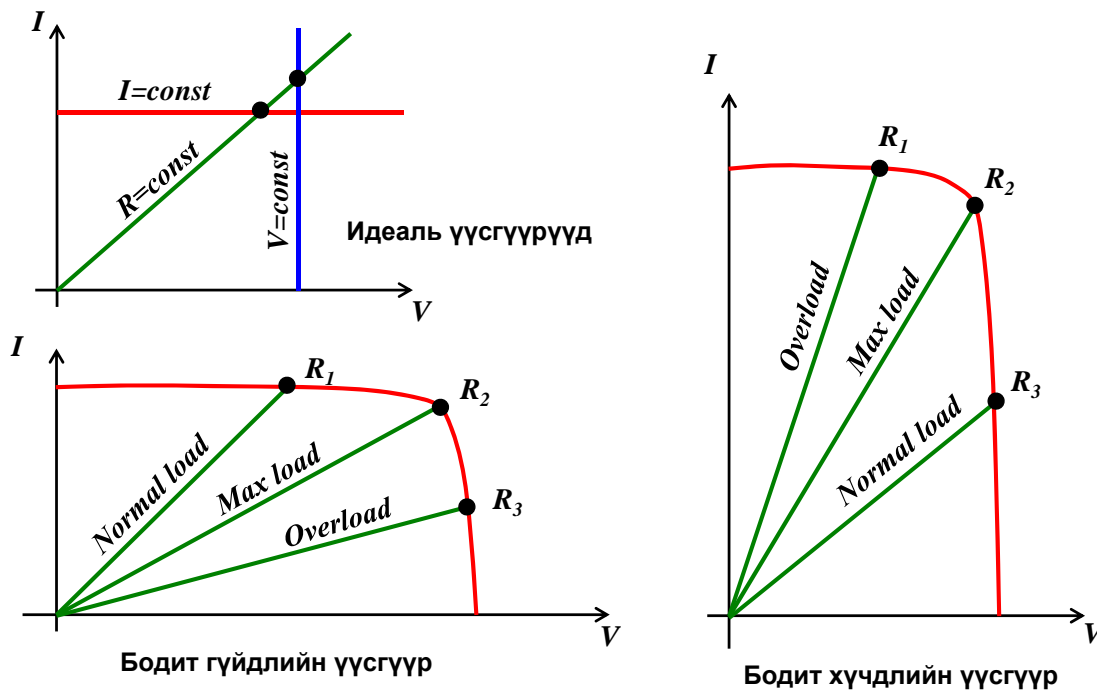
WHAT IS A POWER SOURCE?



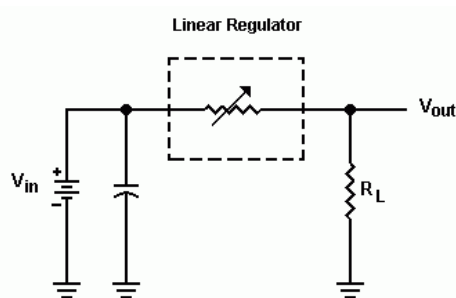
Идеал үүсгүүрүүд



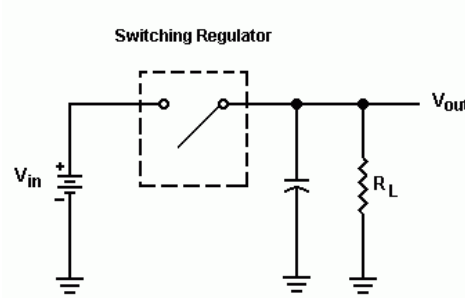
WHAT IS A POWER SOURCE?



WHY SWITCHING REGULATOR?

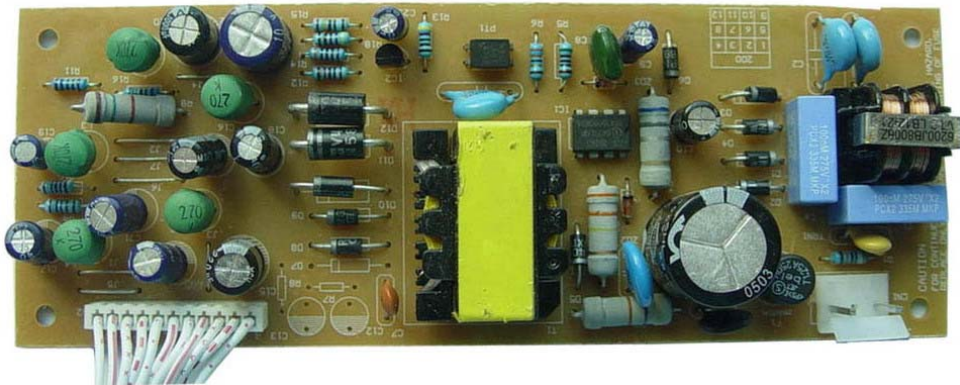


typical efficiencies of 40%,
and reaching as low as 14%,



typically have 85% efficiency
can be up to 95%

WHY SWITCHING REGULATOR?



ADVANTAGES (Давуу талууд):

- АҮК өндөртэй (Энергийн алдагдал бага)
- Гаралтын хүчдлийн тогтворжуулалт сайн
- Оролтын хүчдлийн хэлбэлзэл их байж болдог
- Овор хэмжээ бага
- Өртөг хямд

DISADVANTAGE (Сул тал):

- Төвөгтэй хэлхээтэй, засвар үйлчилгээнд тодорхой мэдлэг шаардагдана.

WHAT TYPE OF SWITCHING REGULATOR?

- **Buck:** used to reduce a DC voltage to a lower DC voltage.
- **Boost:** provides an output voltage that is higher than the input.
- **Buck-Boost (inverting):** an output voltage is generated opposite in polarity to the input.
- **Flyback:** an output voltage that is less than or greater than the input can be generated, as well as multiple outputs.

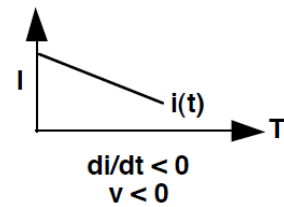
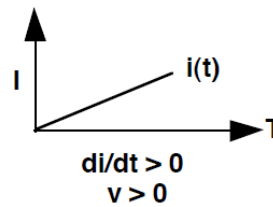
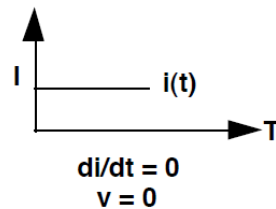
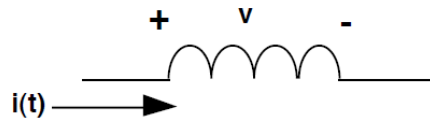
Also, some multiple-transistor converter topologies will be presented:

- **Push-Pull:** A two-transistor converter that is especially efficient at low input voltages.
- **Half-Bridge:** A two-transistor converter used in many off-line applications.
- **Full-Bridge:** A four-transistor converter (usually used in off-line designs) that can generate the highest output power of all the types listed.

SWITCHING FUNDAMENTALS

THE LAW OF INDUCTANCE

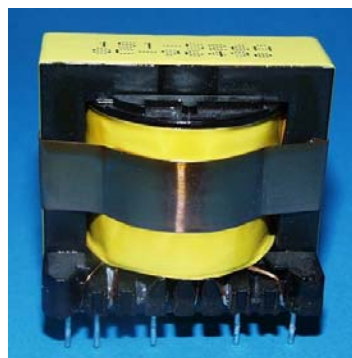
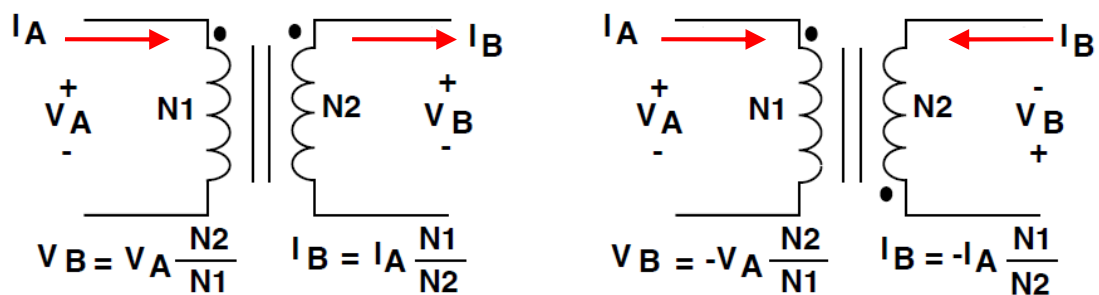
$$V_L = L \frac{dI}{dt}$$



- 1) A voltage across an inductor results **only from a current that changes with time**. **A steady (DC) current flowing in an inductor causes no voltage across it** (except for the tiny voltage drop across the copper used in the windings).
- 2) A **current flowing in an inductor can not change value instantly (in zero time)**, as this would require infinite voltage to force it to happen. However, **the faster the current is changed in an inductor, the larger the resulting voltage will be**.

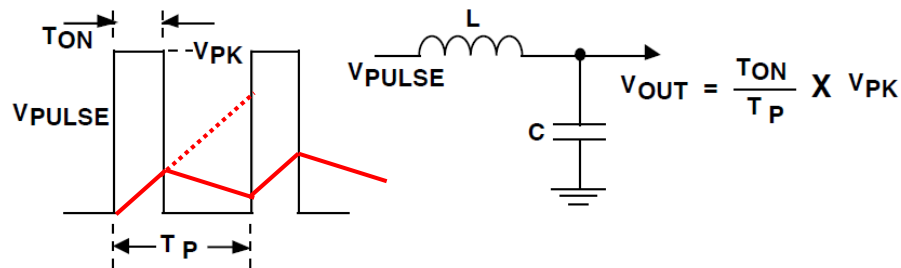
SWITCHING FUNDAMENTALS

TRANSFORMER OPERATION



SWITCHING FUNDAMENTALS

PULSE WIDTH MODULATION (PWM)

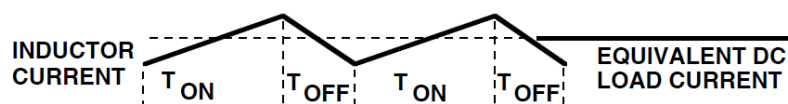
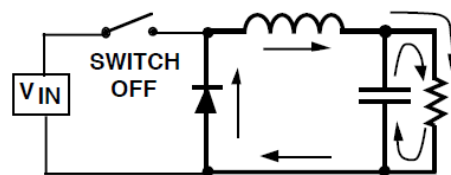
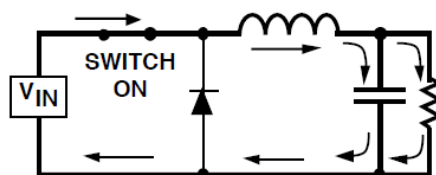
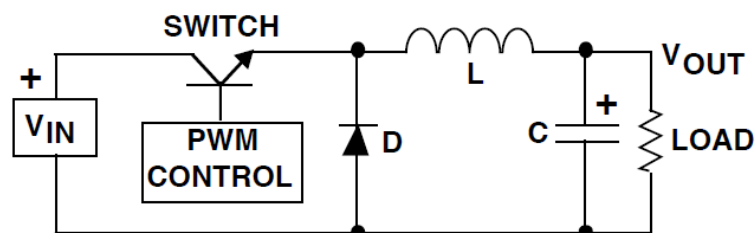


The series of square wave pulses is filtered and provides a **DC output voltage that is equal to the peak pulse amplitude multiplied times the duty cycle** (duty cycle is defined as the switch ON time divided by the total period).

$$D = \frac{T_{ON}}{T_P} < 1$$

SWITCHING CONVERTER TOPOLOGIES

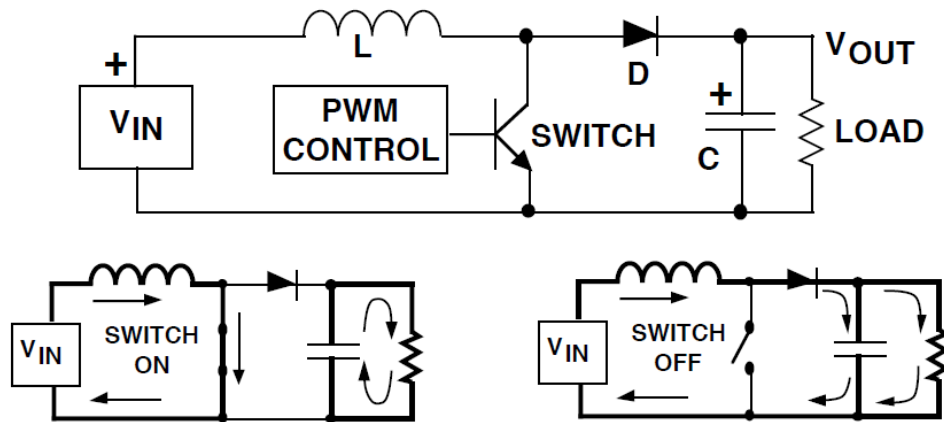
BUCK REGULATOR



$$V_{OUT} = V_{IN} \cdot D$$

SWITCHING CONVERTER TOPOLOGIES

BOOST REGULATOR

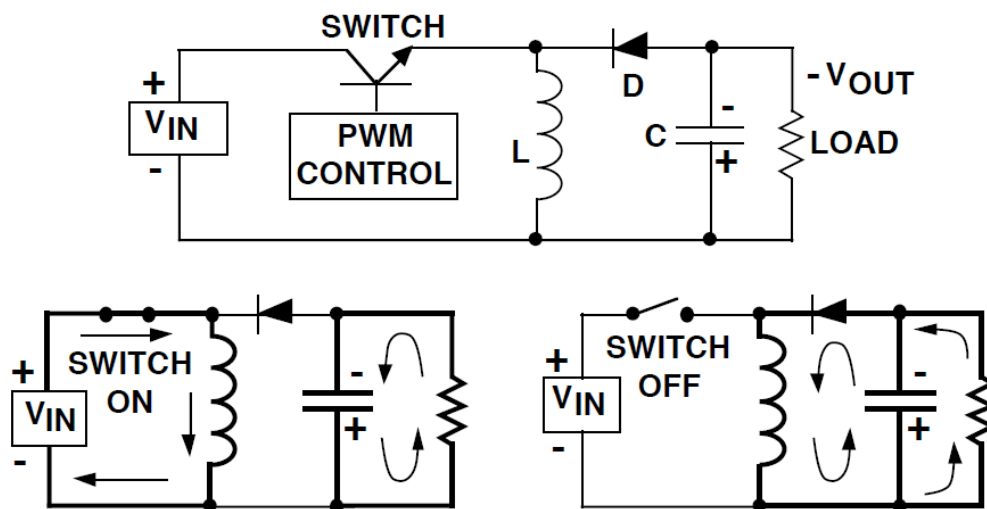


Since the output voltage of the Boost is **higher than the input voltage**, it **follows** that the **output current must be lower than the input current**.

$$V_{OUT} = \frac{V_{IN}}{1-D}$$

SWITCHING CONVERTER TOPOLOGIES

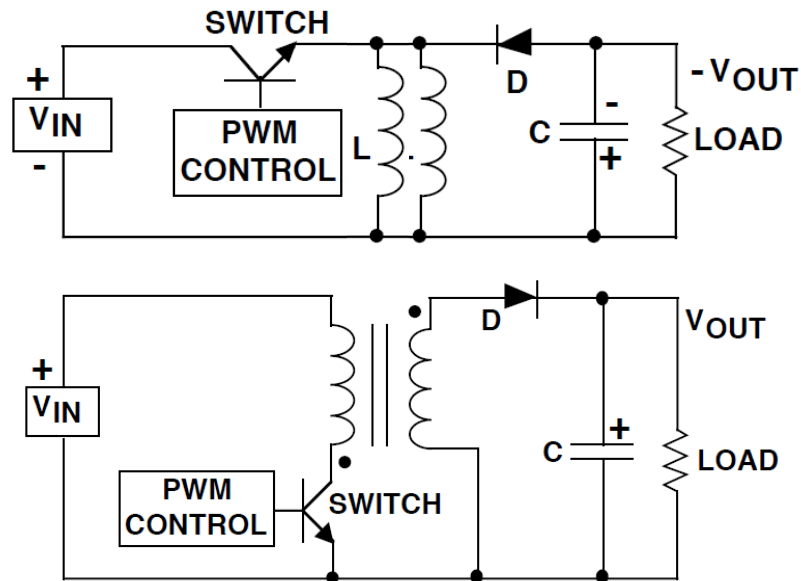
BUCK-BOOST (INVERTING) REGULATOR



$$V_{OUT} = -\frac{D}{1-D} V_{IN}$$

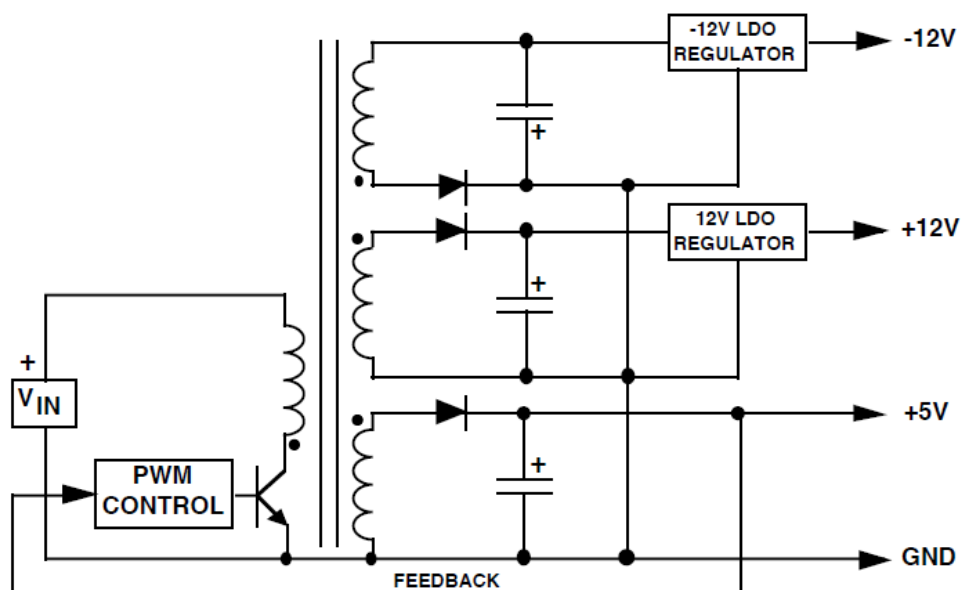
SWITCHING CONVERTER TOPOLOGIES

FLYBACK REGULATOR



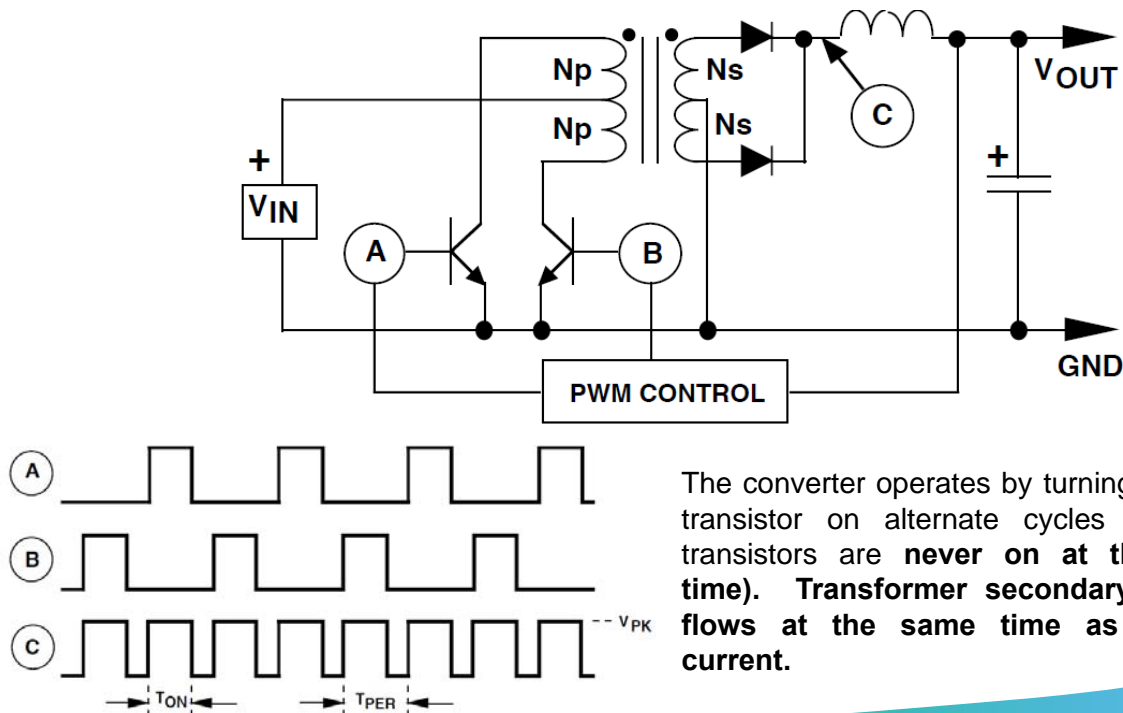
SWITCHING CONVERTER TOPOLOGIES

GENERATING MULTIPLE OUTPUTS



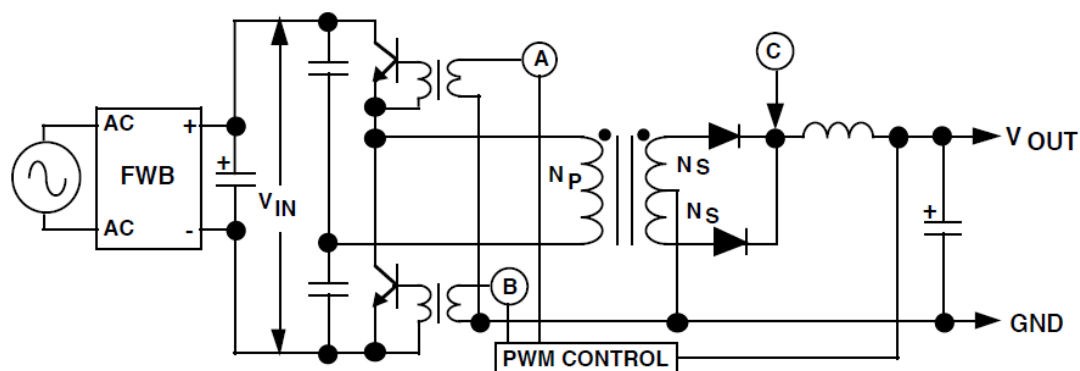
SWITCHING CONVERTER TOPOLOGIES

PUSH-PULL CONVERTER



SWITCHING CONVERTER TOPOLOGIES

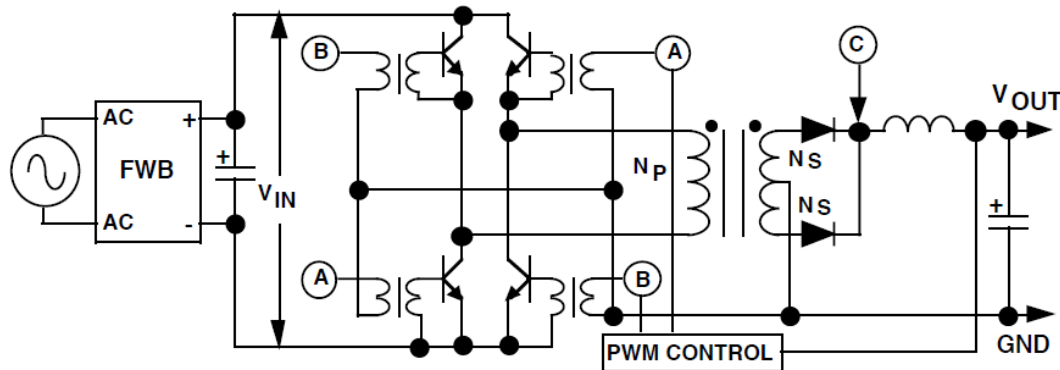
HALF-BRIDGE CONVERTER



In a Half-Bridge converter, **primary and secondary current flow in the transformer at the same time (when either transistor is on), supplying the load current and charging the output capacitor.** The output capacitor discharges into the load **only during the time when both transistors are off**. Easy for changing 220/110 applications.

SWITCHING CONVERTER TOPOLOGIES

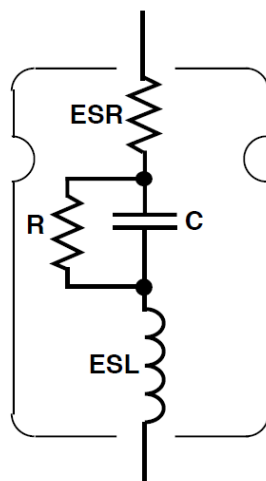
FULL-BRIDGE CONVERTER



The transformer primary is driven by the **full voltage V_{IN}** when **either of the** transistor sets ("A" set or "B" set) turns on. The full input voltage utilization means the **Full-Bridge can produce the most load power of all the converter types.**

SWITCHING CONVERTER TOPOLOGIES

CAPACITOR PARASITICS AFFECTING SWITCHING REGULATOR PERFORMANCE



ESR: The **ESR (Equivalent Series Resistance)** causes internal heating due to power dissipation as the ripple current flows into and out of the capacitor. The capacitor can fail if ripple current exceeds maximum ratings.

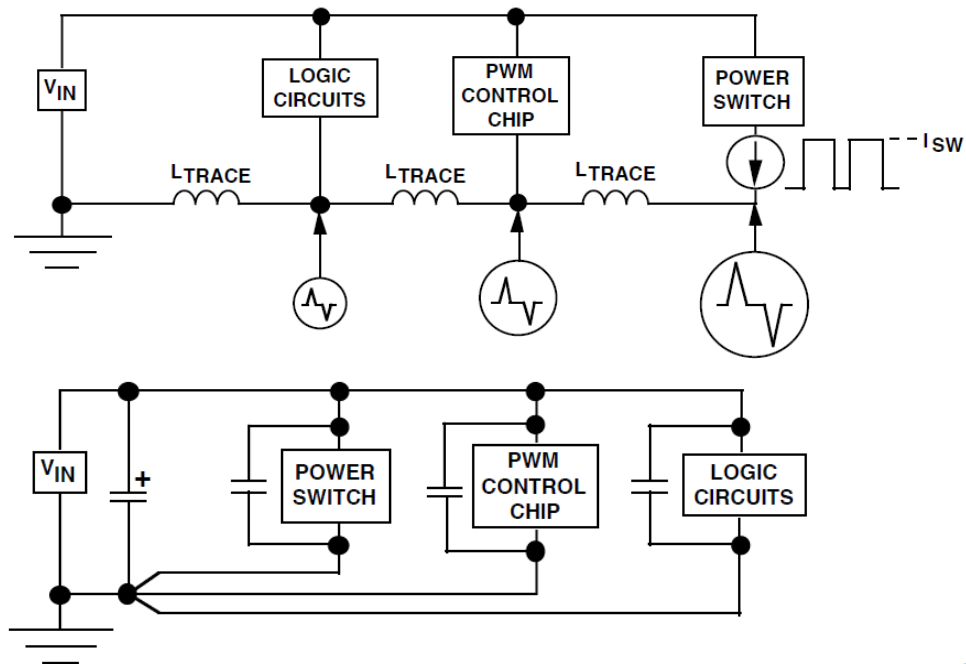
Excessive output voltage ripple will result from high ESR, and regulator loop instability is also possible. ESR is highly dependent on temperature, increasing very quickly at temperatures below about 10 °C.

ESL: The **ESL (Effective Series Inductance)** limits the high frequency effectiveness of the capacitor. High ESL is the reason electrolytic capacitors need to be bypassed by film or ceramic capacitors to provide good high-frequency performance.

The ESR, ESL and C within the capacitor form a resonant circuit, whose frequency of resonance should be as high as possible. Switching regulators generate ripple voltages on their outputs with very high frequency (>10 MHz) components, which can cause ringing on the output voltage if the capacitor resonant frequency is low enough to be near these frequencies.

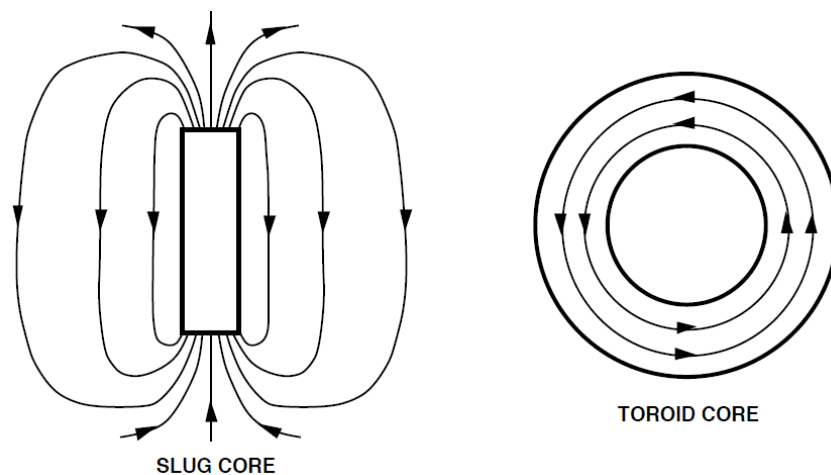
APPLICATION HINTS FOR SWITCHING REGULATORS

PROPER GROUNDING



APPLICATION HINTS FOR SWITCHING REGULATORS

MAGNETIC FLUX





POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

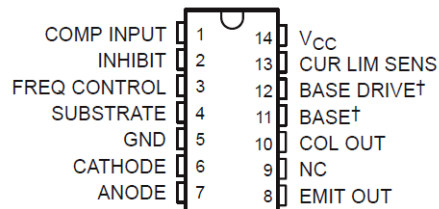
CIRCUITS ON TL497A

TL497A SWITCHING VOLTAGE REGULATORS

SLVS009D – JUNE 1976 – REVISED JULY 1999

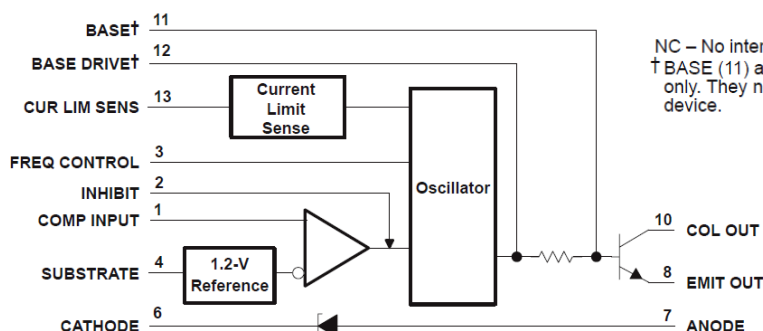
- High Efficiency . . . 60% or Greater
- Output Current . . . 500 mA
- Input Current Limit Protection
- TTL-Compatible Inhibit
- Adjustable Output Voltage
- Input Regulation . . . 0.2% Typ
- Output Regulation . . . 0.4% Typ
- Soft Start-Up Capability

D, N, OR PW PACKAGE (TOP VIEW)



NC – No internal connection

† BASE (11) and BASE DRIVE (12) are used for device testing only. They normally are not used in circuit applications of the device.



$$t_{ON} = 91k\Omega \cdot C_T$$



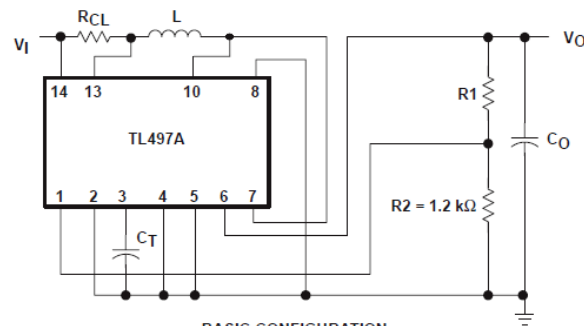
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CIRCUITS ON TL497A

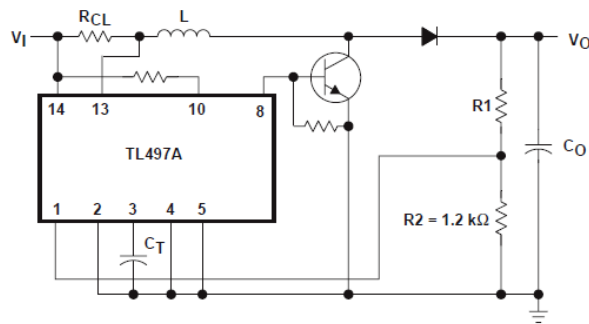
recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V _{CC}		4.5	12	V
High-level input voltage, V _{IH}	INHIBIT pin	2.5		V
Low-level input voltage, V _{IL}	INHIBIT pin		0.8	V
Output voltage	Step-up configuration (see Figure 1)	V _I + 2	30	V
	Step-down configuration (see Figure 2)	V _{ref}	V _I - 1	
	Inverting regulator (see Figure 3)	-V _{ref}	-25	
Power switch current			500	mA
Diode forward current			500	mA
Operating free-air temperature range, T _A	TL497AC	0	70	°C
	TL497AI	-40	85	

APPLICATION INFORMATION



BASIC CONFIGURATION
(Peak Switching Current = $I_{(PK)} < 500$ mA)



EXTENDED POWER CONFIGURATION
(using external transistor)

DESIGN EQUATIONS

$$I_{(PK)} = 2 I_O \max \left[\frac{V_O}{V_I} \right]$$

$$L (\mu H) = \frac{V_I}{I_{(PK)}} t_{on} (\mu s)$$

Choose L (50 to 500 μH), calculate t_{on} (25 to 150 μs)

$$C_T (pF) \approx 12 t_{on} (\mu s)$$

$$R_1 = (V_O - 1.2 V) k\Omega$$

$$R_{CL} = \frac{0.5 V}{I_{(PK)}}$$

$$C_O (\mu F) \approx t_{on} (\mu s) \frac{\left[\frac{V_I}{V_O} I_{(PK)} + I_O \right]}{V_{ripple (PK)}}$$

Figure 1. Positive Regulator, Step-Up Configurations

Start a Design Step by Step

Enter your specification below and press "Recommend Design"

☒ AC Input $V_{in_{max}}$ 240.0 V_{rms} V_{O1} 12.0 V
☐ DC Input $V_{in_{min}}$ 100.0 V_{rms} I_{m1} 4.0 A

<http://www.poweresim.com/>

Power Supply Application: Adaptor



Recommend Design

Start a Design from Topology

User can start a design from topologies below

[More Topologies...](#)

- Flyback AC-DC
- PFC CCM
- PFC DCM
- LLC DC-DC
- Full Bridge DC-DC
- Pri. FB LED Bulb Driver
- RCC Flyback AC-DC
- Standalone Xformer Design
- [More Topologies...](#)

Start a Design from Reference

User can start a design from the below reference design too



- 5V 700mA Charger AP3708
 - 5V 750mA Charger AP3706
 - 5V 850mA Charger AP3706



- 16 V 60 W ICE3DS01
 - 160 W PFC TDA4863
 - 300 W PFC ICE1PCS01
 - 5 V 12 W ICE3B0565
 - LCD 24 V 150 W with PFC



- 160 W PFC LCD AC-DC
 - 24 V 6.3 A 150 W LCD DC-DC
 - Boost Converter Tutorial Template
 - Buck Converter Tutorial Template



Thank You !