Convertidores con aislamiento

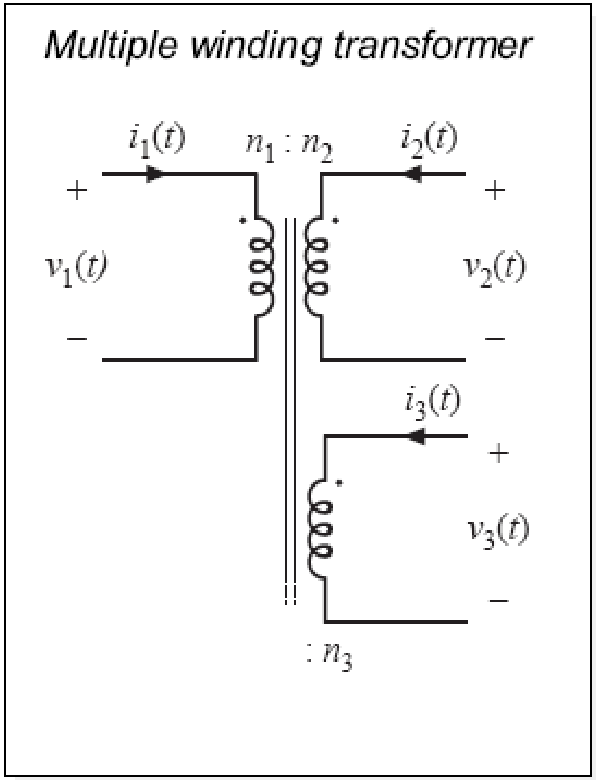
Aislamiento

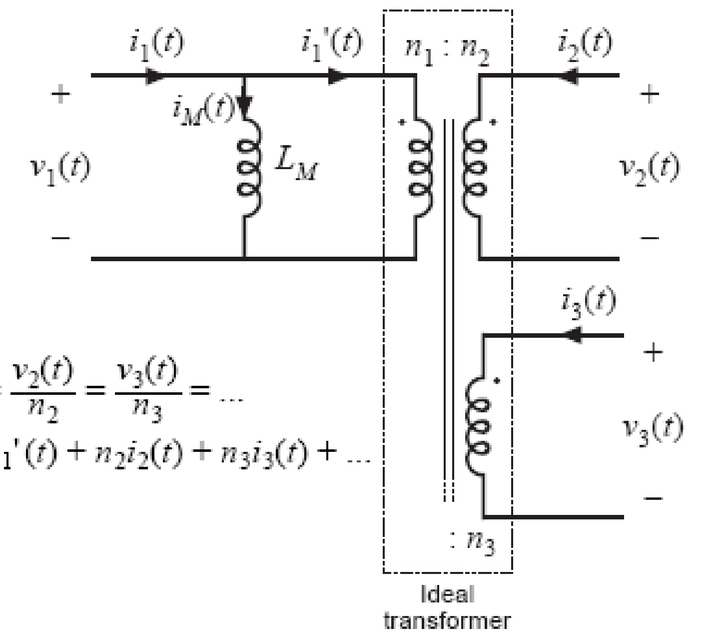
Objetivos

- **Aislamiento entre entrada y salida por requisitos de seguridad**
- **Reducción eliminación del transformador de línea por uno de alta frecuencia**
- **Minimizar los estreses de corriente y tensión cuando se precisan grandes relaciones de conversión (n)**
- **Obtener varias tensiones de salida**

Aislamiento

Modelo simple de transformador





$$\frac{v_1(t)}{n_1} = \frac{v_2(t)}{n_2} = \frac{v_3(t)}{n_3} = \ldots$$

$$0 = n_1 i_1'(t) + n_2 i_2(t) + n_3 i_3(t) + \ldots$$

Aislamiento

Balance de voltios-segundo

The magnetizing inductance is a real inductor, obeying

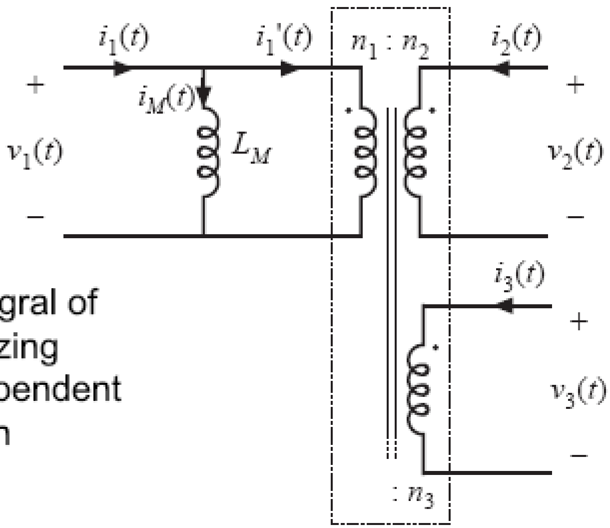
$$v_1(t) = L_M \frac{di_M(t)}{dt}$$

integrate:

$$i_M(t) - i_M(0) = \frac{1}{L_M} \int_0^t v_1(\tau)\,d\tau$$

Magnetizing current is determined by integral of the applied winding voltage. The magnetizing current and the winding currents are independent quantities. Volt-second balance applies: in steady-state, $i_M(T_s) = i_M(0)$, and hence

$$0 = \frac{1}{T_s} \int_0^{T_s} v_1(t)\,dt$$



Ideal transformer

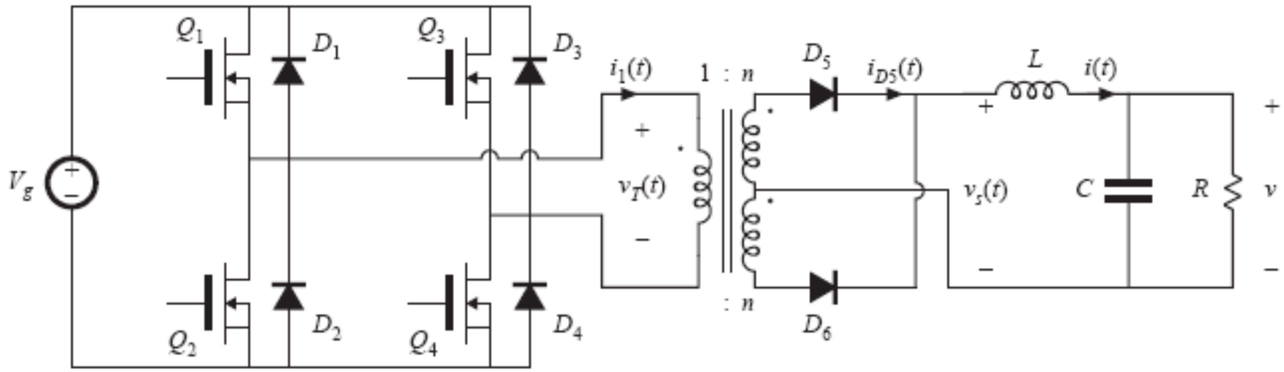
Aislamiento

Reset del transformador

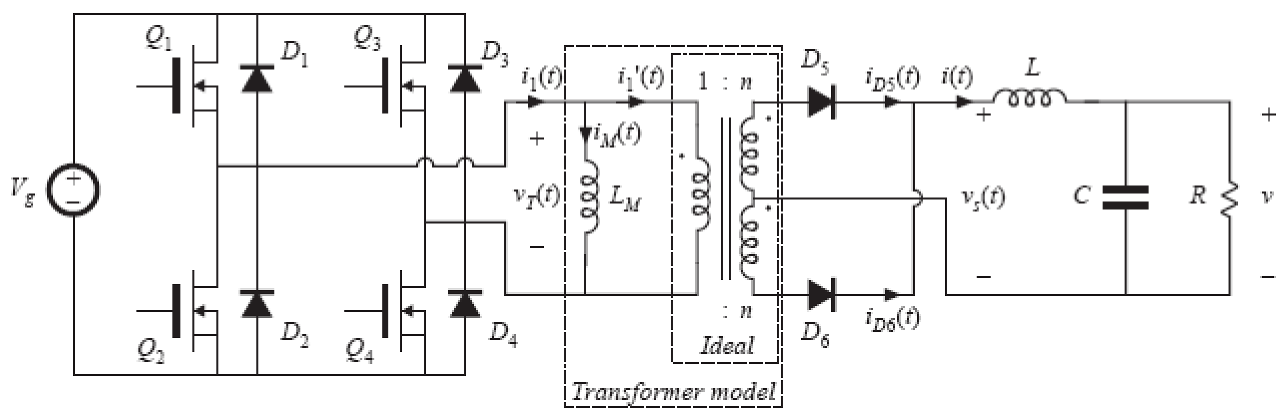
Mecanismo para obtener
Balance voltios-segundo de la inductancia magnetizante

Puente completo

Full-bridge isolated buck converter

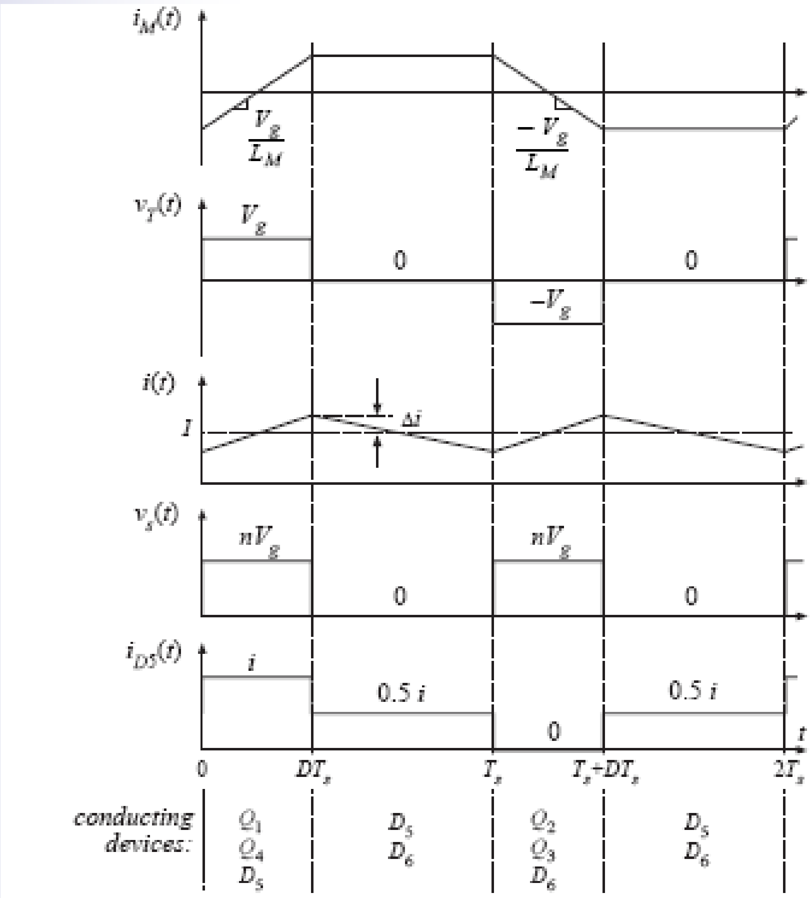


Circuito equivalente del transformador



Puente completo

Formas de onda



- During first switching period: transistors Q_1 and Q_4 conduct for time DT_s, applying volt-seconds $V_g DT_s$ to primary winding
- During next switching period: transistors Q_2 and Q_3 conduct for time DT_s, applying volt-seconds $-V_g DT_s$ to primary winding
- Transformer volt-second balance is obtained over two switching periods
- Effect of nonidealities?

Puente completo

Efecto de no idealidades

Volt-seconds applied to primary winding during first switching period:

$$(V_g - (Q_1 \text{ and } Q_4 \text{ forward voltage drops}))(\,Q_1 \text{ and } Q_4 \text{ conduction time})$$

Volt-seconds applied to primary winding during next switching period:

$$-(V_g - (Q_2 \text{ and } Q_3 \text{ forward voltage drops}))(\,Q_2 \text{ and } Q_3 \text{ conduction time})$$

These volt-seconds never add to *exactly* zero.

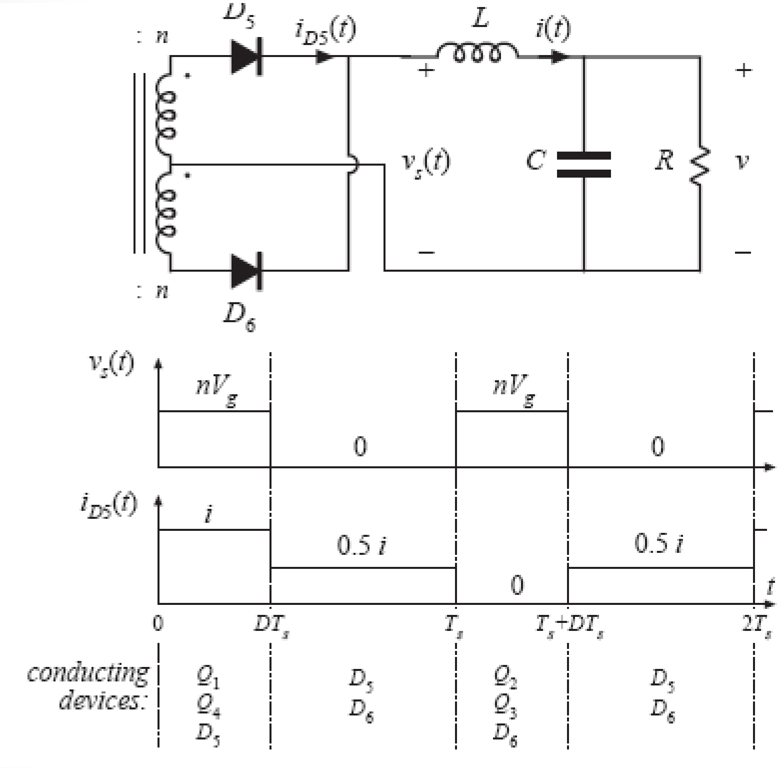
Net volt-seconds are applied to primary winding

Magnetizing current slowly increases in magnitude

Saturation can be prevented by placing a capacitor in series with primary, or by use of current programmed mode (Chapter 12)

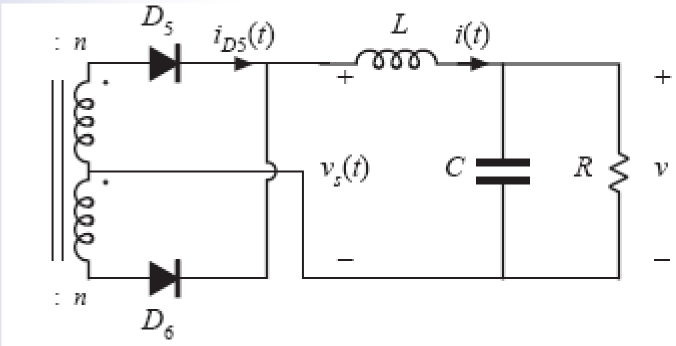
Puente completo

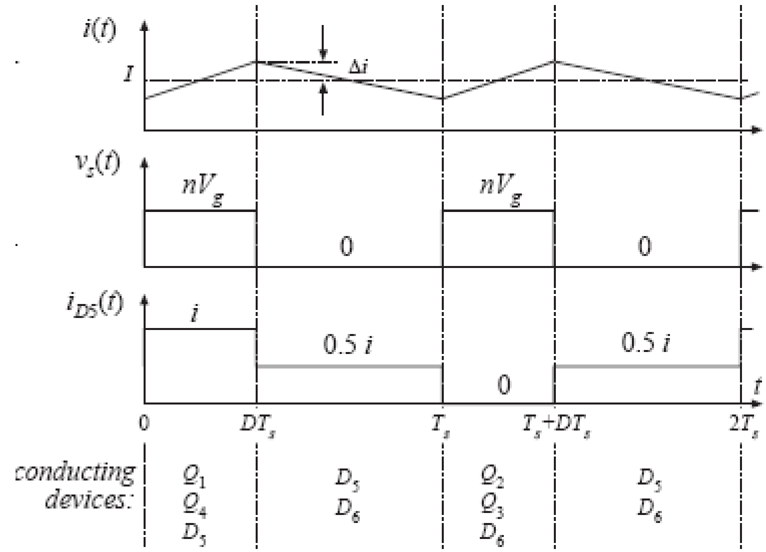
Operación de los diodos de secundario



Puente completo

Balance voltios-segundo L secundario





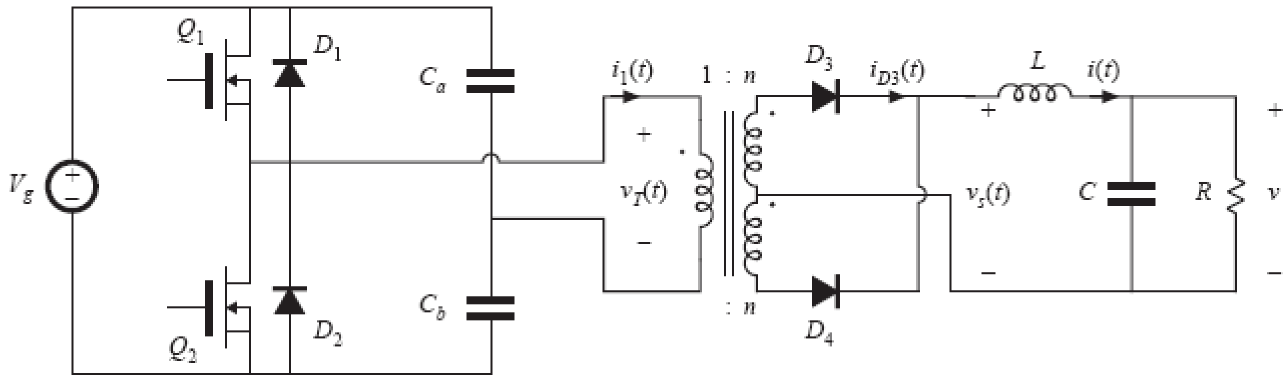
$$V = \langle v_s \rangle$$

$$V = nDV_g$$

$$M(D) = nD$$

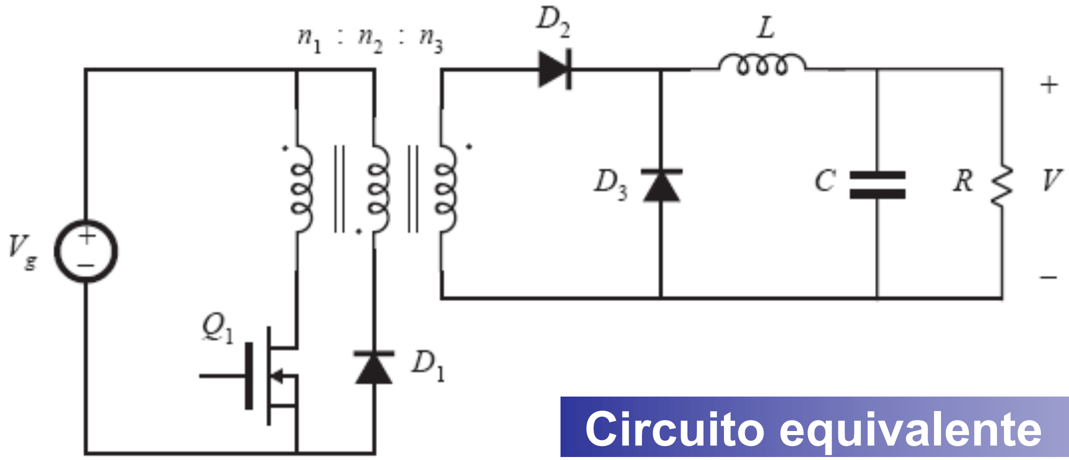
Convertidor reductor con relación de vueltas

Medio puente con aislamiento



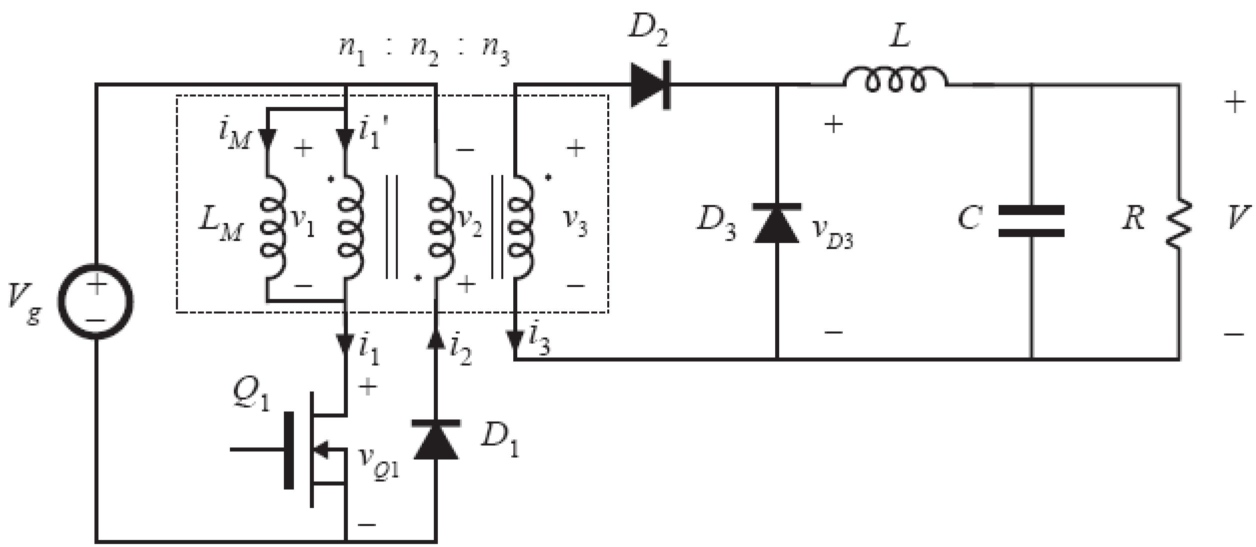
- Replace transistors Q_3 and Q_4 with large capacitors
- Voltage at capacitor centerpoint is $0.5V_g$
- $v_s(t)$ is reduced by a factor of two
- $M = 0.5\ nD$

Convertidor directo (forward)



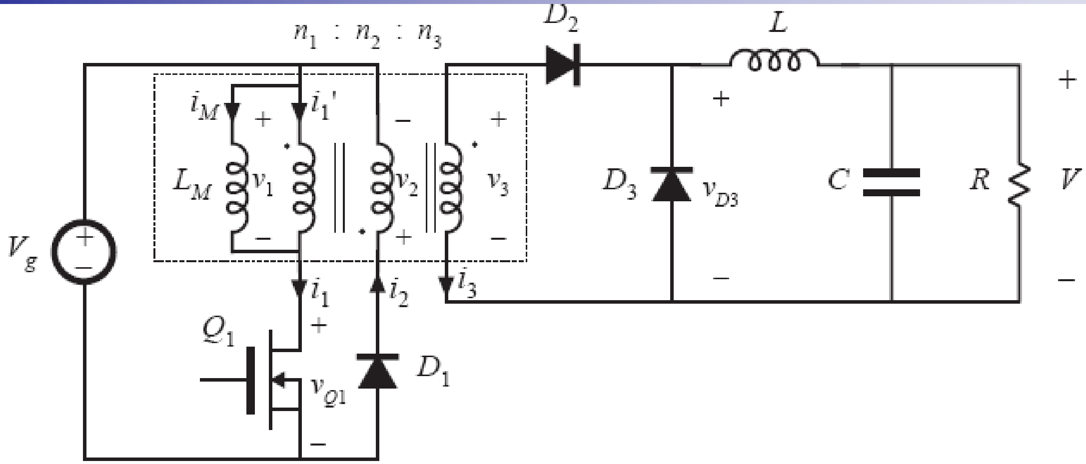
- Buck-derived transformer-isolated converter
- Single-transistor and two-transistor versions
- Maximum duty cycle is limited
- Transformer is reset while transistor is off

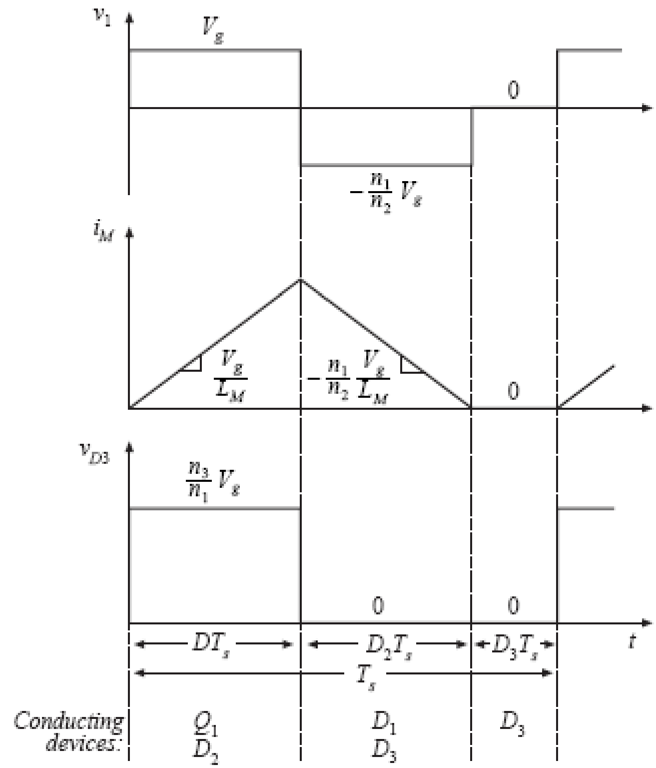
Circuito equivalente



Convertidor directo (forward)

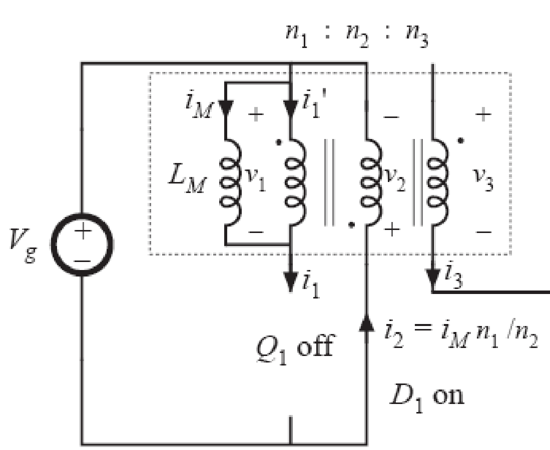
Formas de onda I

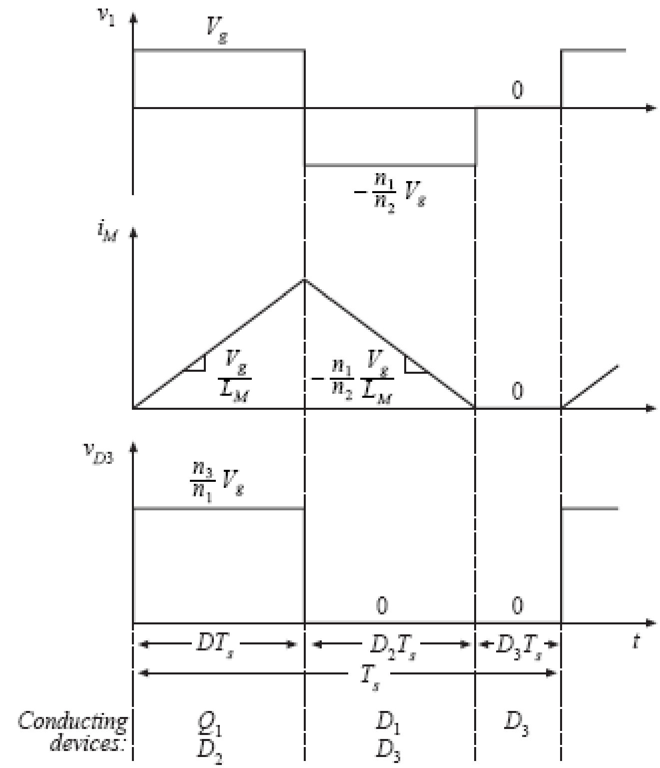




Convertidor directo (forward)

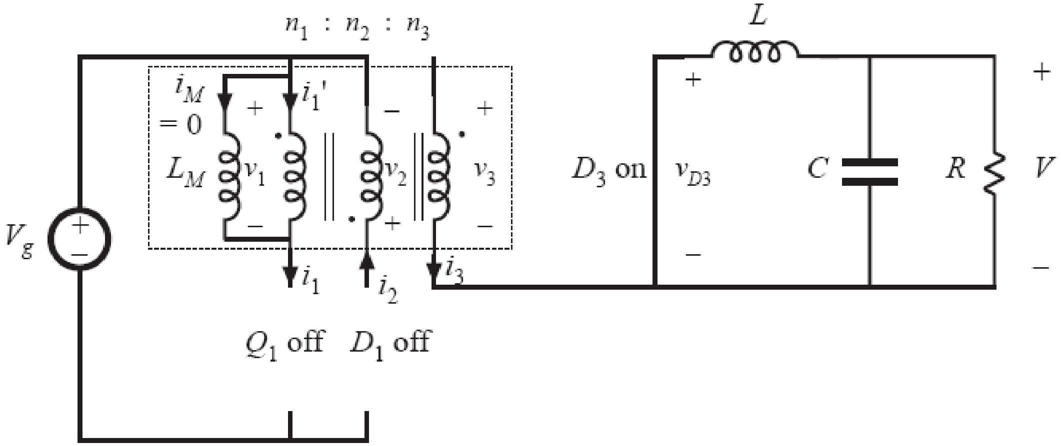
Formas de onda II

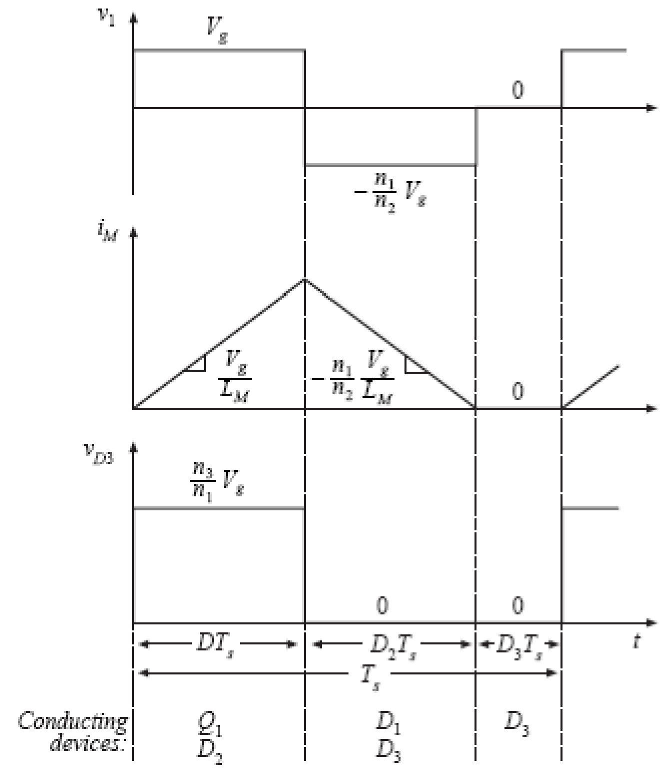




Convertidor directo (forward)

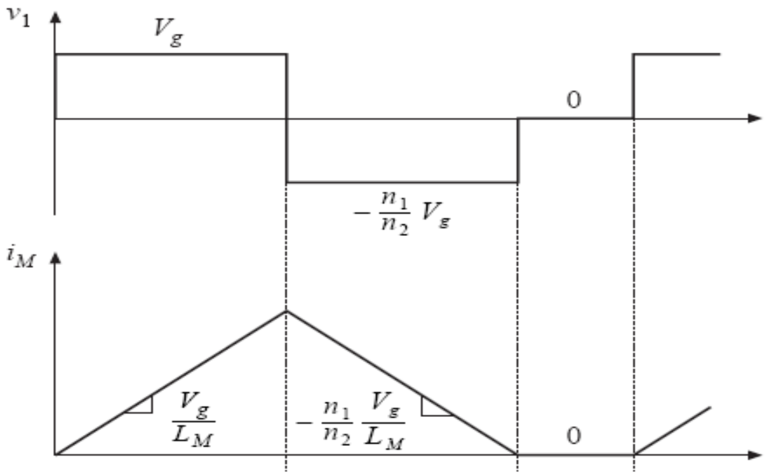
Formas de onda III



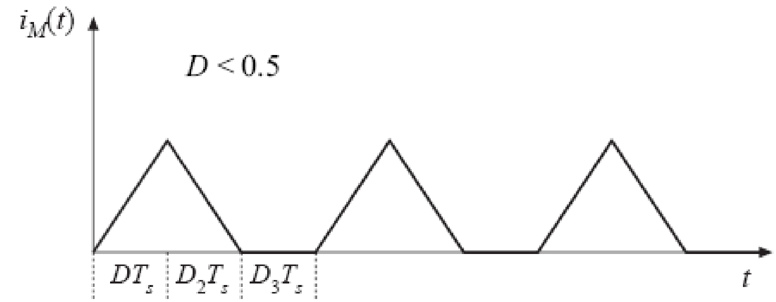


Convertidor directo (forward)

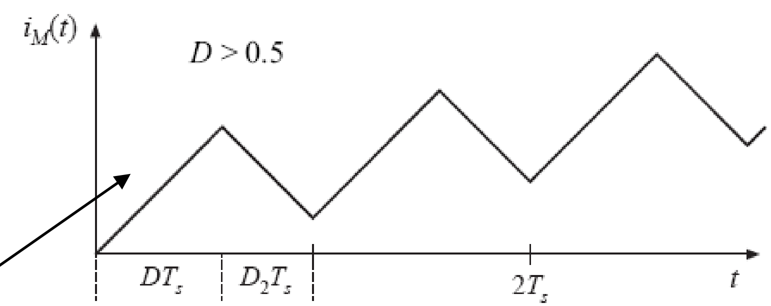
Balance v-s en magnetizante



$$\langle v_1\rangle = D(V_g) + D_2(-V_g n_1/n_2) + D_3(0) = 0$$

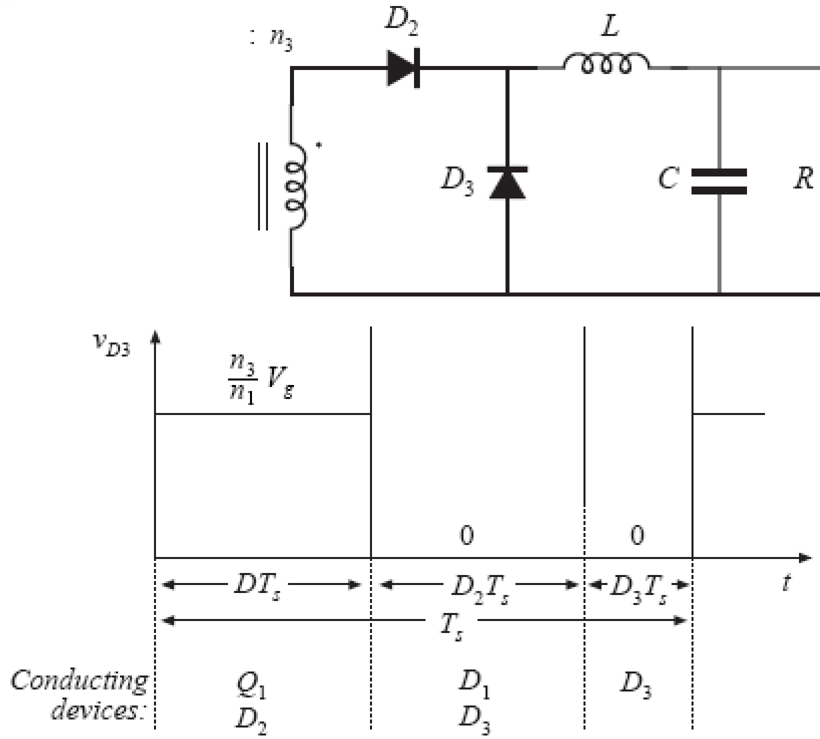


D>0.5



Convertidor directo (forward)

Relación de conversión



$$\langle v_{D3} \rangle = V = \frac{n_3}{n_1} D V_g$$

Convertidor directo (forward)

Relación entre máximo ciclo de trabajo y estrés en transistor

Maximum duty cycle limited to

$$D \leq \frac{1}{1 + \frac{n_2}{n_1}}$$

which can be increased by increasing the turns ratio n_2 / n_1. But this increases the peak transistor voltage:

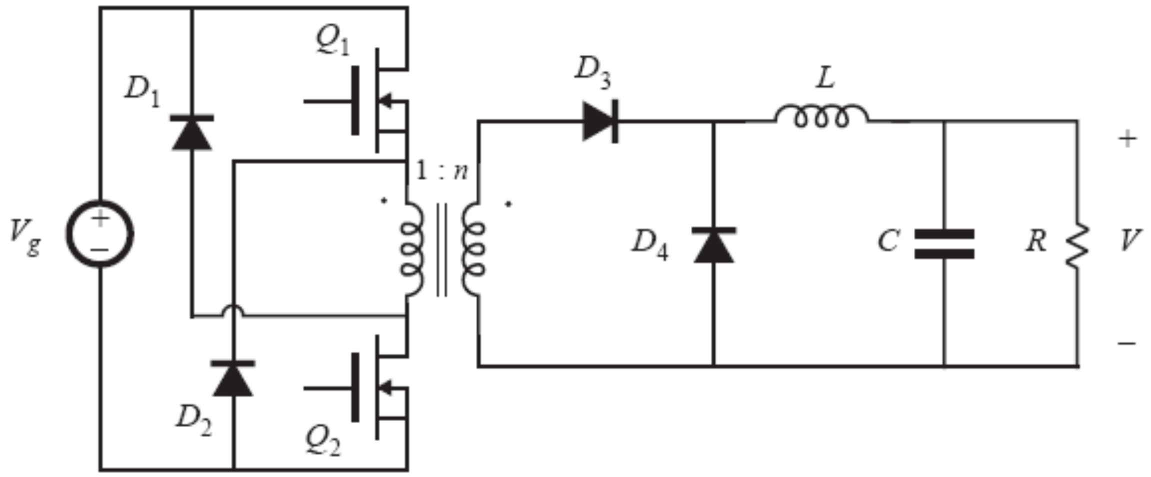
$$\max\left(v_{Q1}\right) = V_g\left(1 + \frac{n_1}{n_2}\right)$$

For $n_1 = n_2$

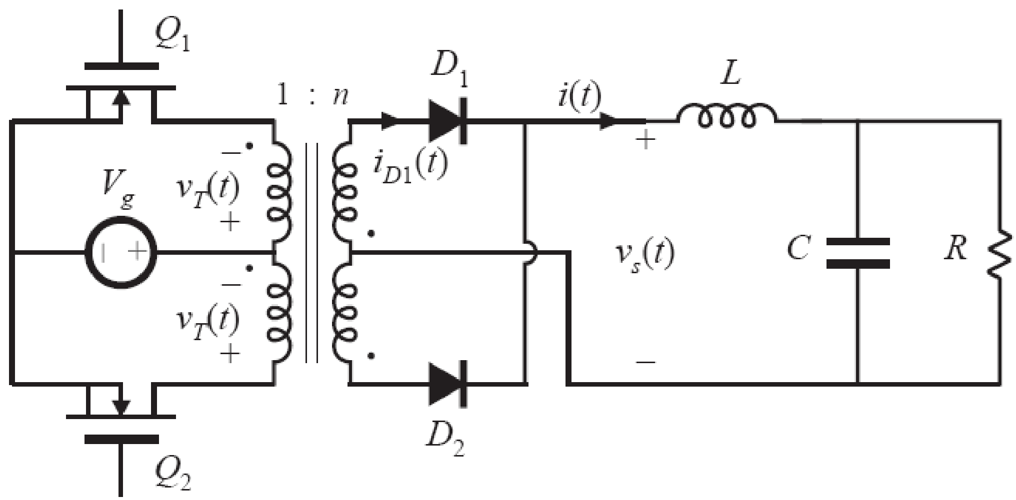
$$D \leq \frac{1}{2} \quad \text{and} \quad \max(v_{Q1}) = 2V_g$$

Convertidor directo de dos transistores

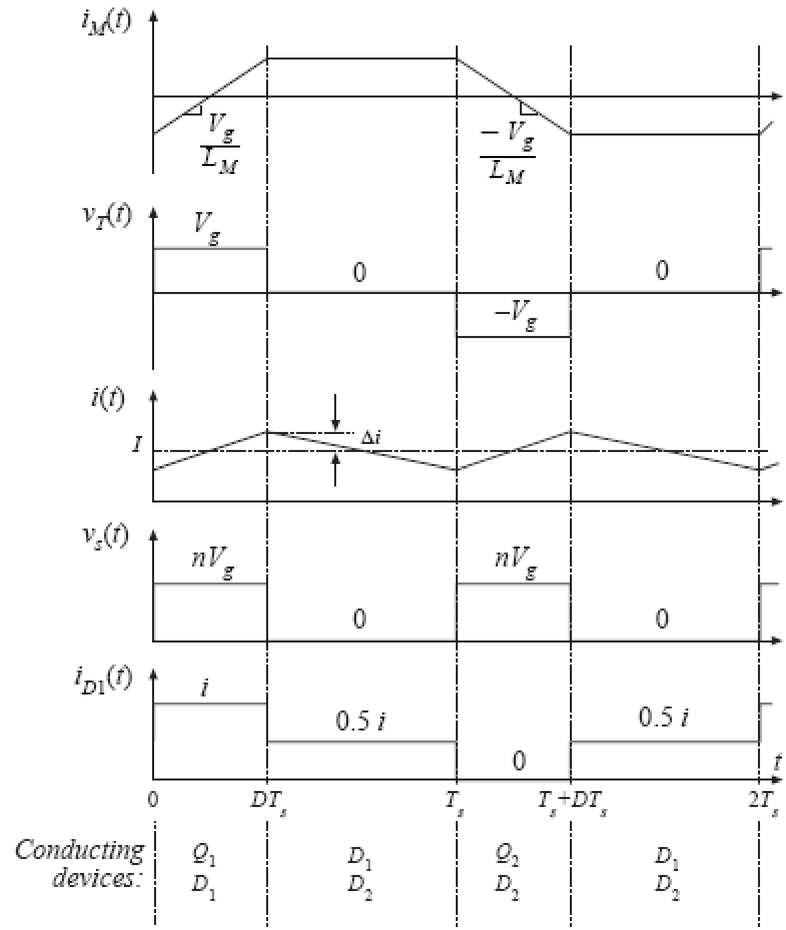
Relación de conversión



Convertidor Push-pull

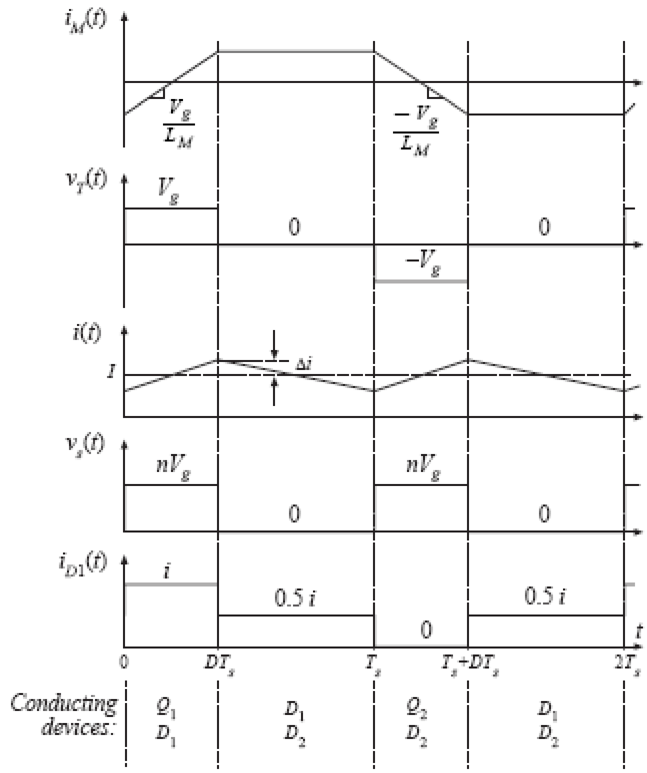


$V = nDV_g$ $\qquad 0 \leq D \leq 1$



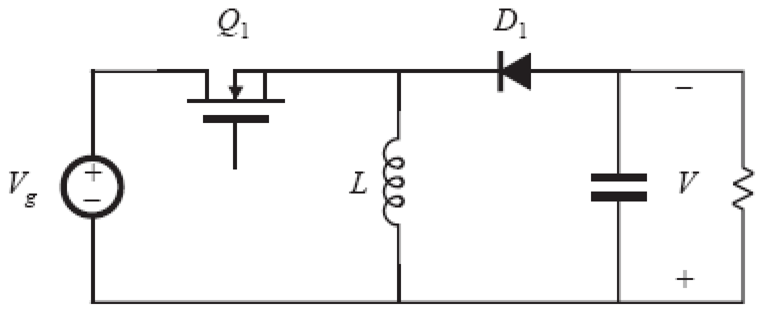
Convertidor Push-pull

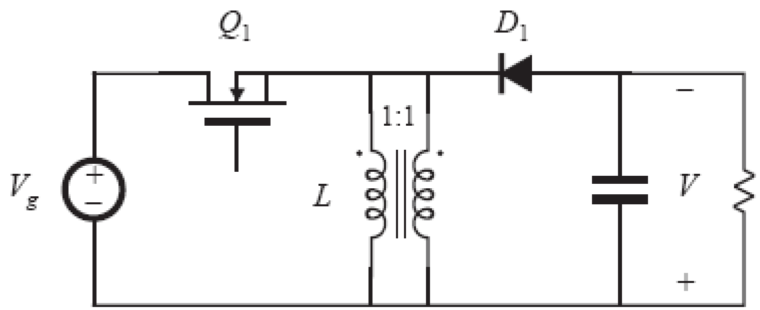
Formas de onda



Convertidor Flyback

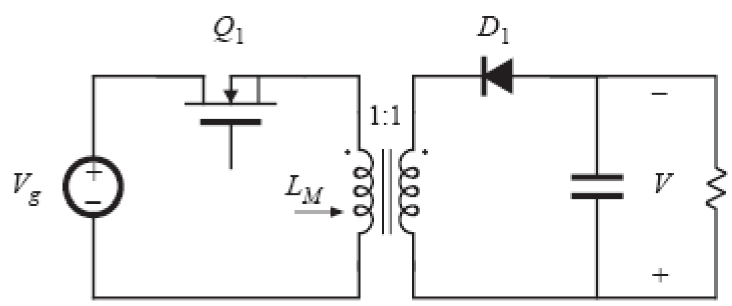
Derivación del flyback

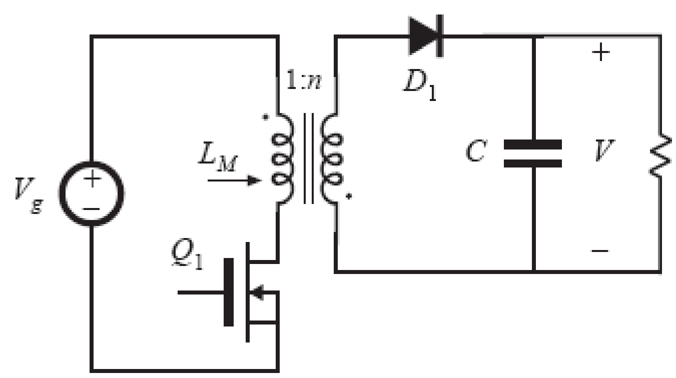




Convertidor Flyback

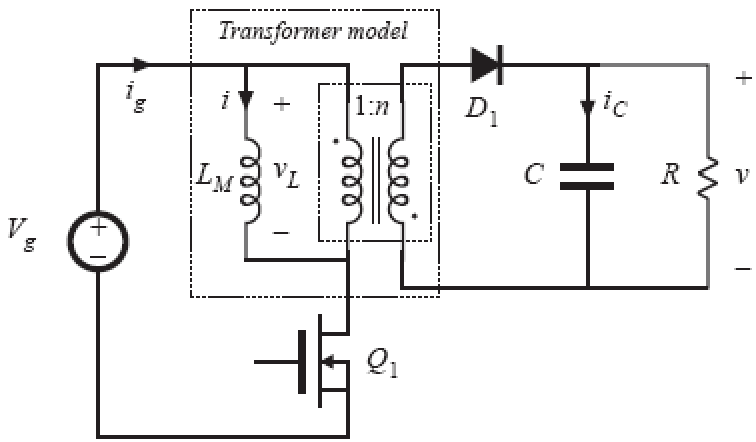
Derivación del flyback





Convertidor Flyback

Transformador del flyback

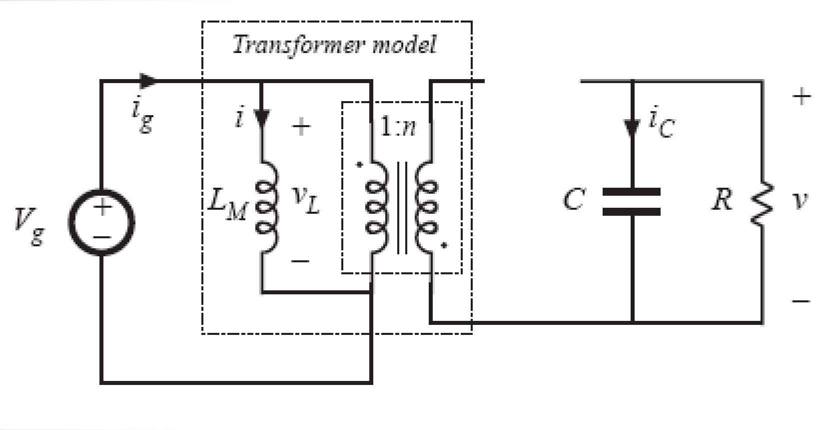


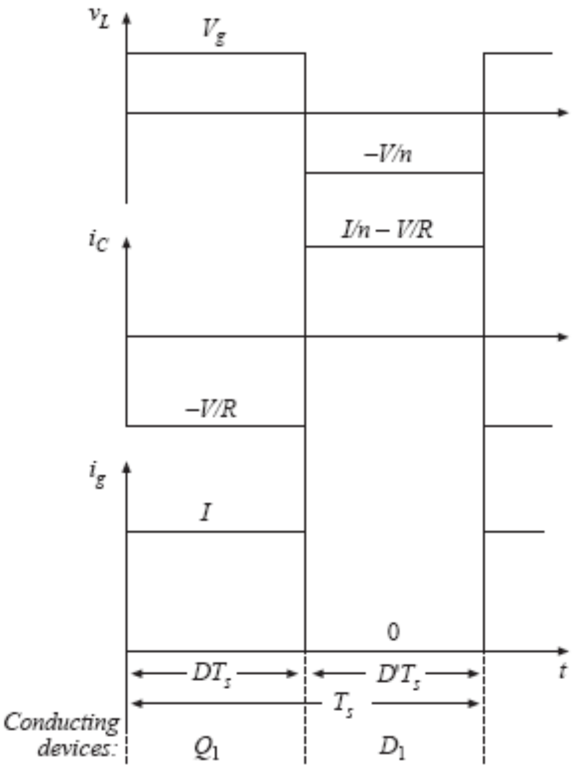
- A two-winding inductor
- Symbol is same as transformer, but function differs significantly from ideal transformer
- Energy is stored in magnetizing inductance
- Magnetizing inductance is relatively small

- Current does not simultaneously flow in primary and secondary windings
- Instantaneous winding voltages follow turns ratio
- Instantaneous (and rms) winding currents do not follow turns ratio
- Model as (small) magnetizing inductance in parallel with ideal transformer

Convertidor Flyback

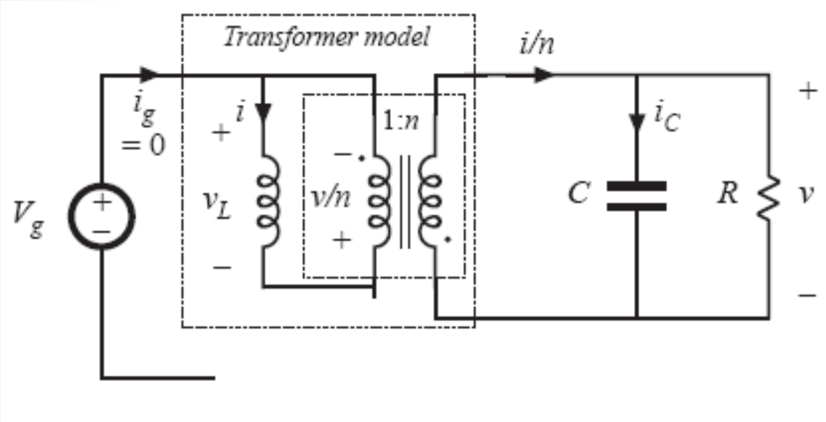
Transformador del flyback

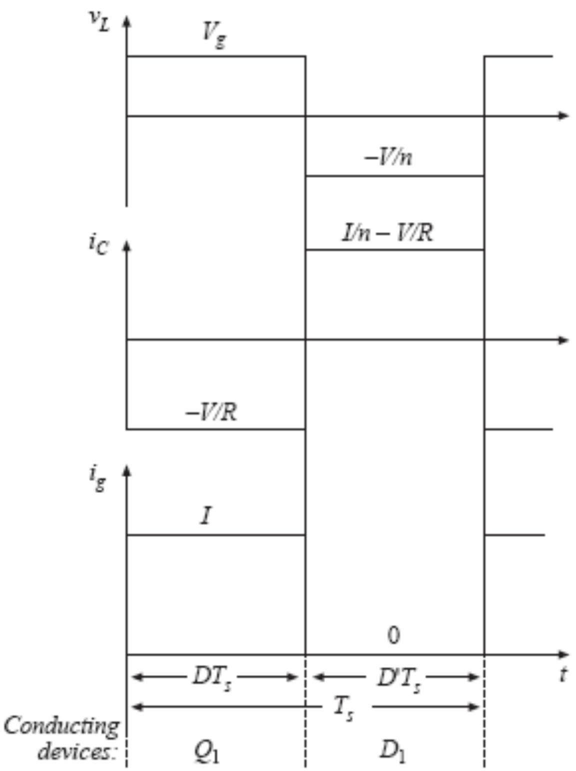




Convertidor Flyback

Transformador del flyback





Flyback

Características

- Widely used in low power and/or high voltage applications
- Low parts count
- Multiple outputs are easily obtained, with minimum additional parts
- Cross regulation is inferior to buck-derived isolated converters
- Often operated in discontinuous conduction mode
- DCM analysis: DCM buck-boost with turns ratio

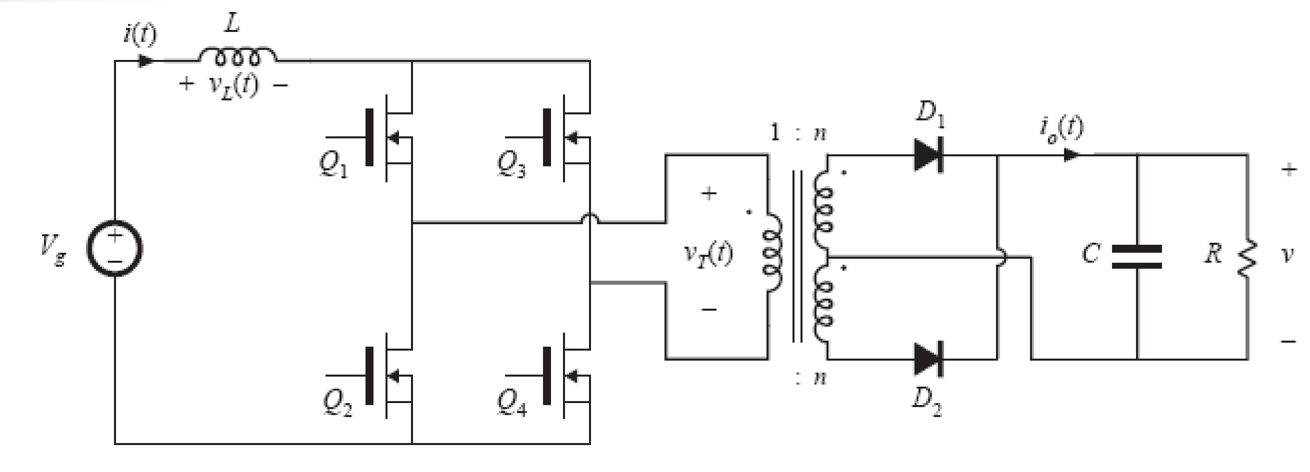
Convertidores derivados del Boost

- A wide variety of boost-derived isolated dc-dc converters can be derived, by inversion of source and load of buck-derived isolated converters:
  - full-bridge and half-bridge isolated boost converters
  - inverse of forward converter: the “reverse” converter
  - push-pull boost-derived converter

Of these, the full-bridge and push-pull boost-derived isolated converters are the most popular, and are briefly discussed here.

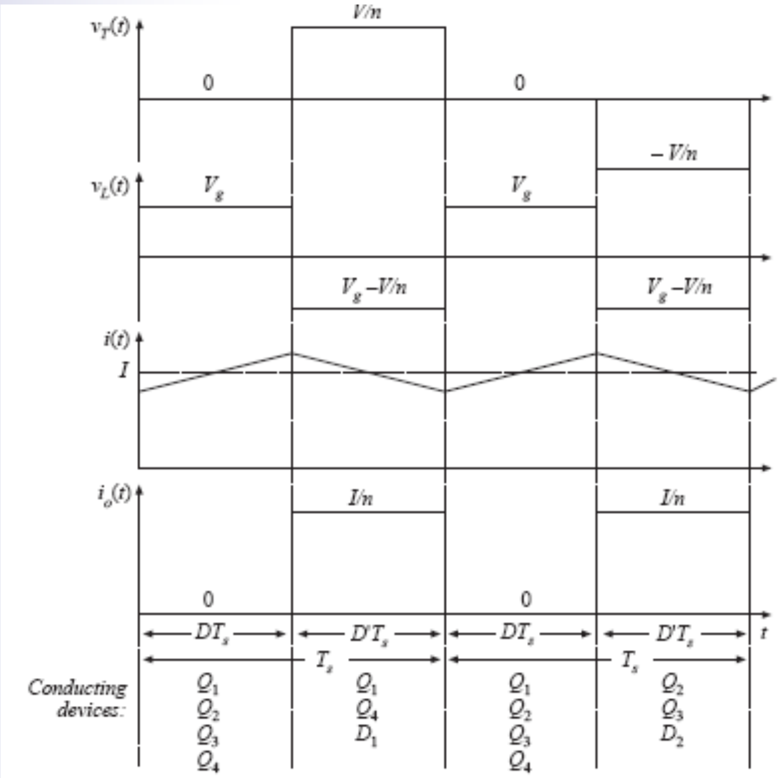
Puente completo derivado del boost

Características



Puente completo derivado del boost

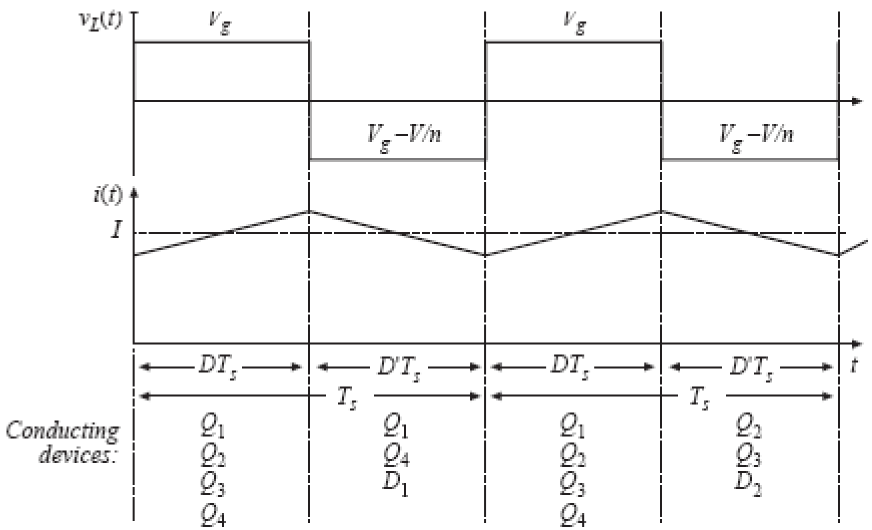
Reset del transformador



- As in full-bridge buck topology, transformer volt-second balance is obtained over two switching periods.
- During first switching period: transistors Q_1 and Q_4 conduct for time DT_s, applying volt-seconds VDT_s to secondary winding.
- During next switching period: transistors Q_2 and Q_3 conduct for time DT_s, applying volt-seconds $-VDT_s$ to secondary winding.

Puente completo derivado del boost

Relación de conversión



Application of volt-second balance to inductor voltage waveform:

$$\langle v_L \rangle = D\left(V_g\right) + D'\left(V_g - \frac{V}{n}\right) = 0$$

Solve for $M(D)$:

$$M(D) = \frac{V}{V_g} = \frac{n}{D'}$$

—boost with turns ratio n