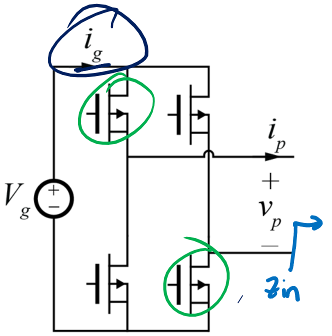
# Switch Network Sinusoidal Analysis




**Fourier Series:**

$$b_1 = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)\sin(x)\,dx$$

**For $v_p(t)$:**

$$b_1 = \frac{2}{T_s}\int_0^{T_s} v_p(t)\sin(2\pi f_s t)\,dt$$

$\theta = 2\pi f_s t$

$d\theta = 2\pi f_s\,dt$

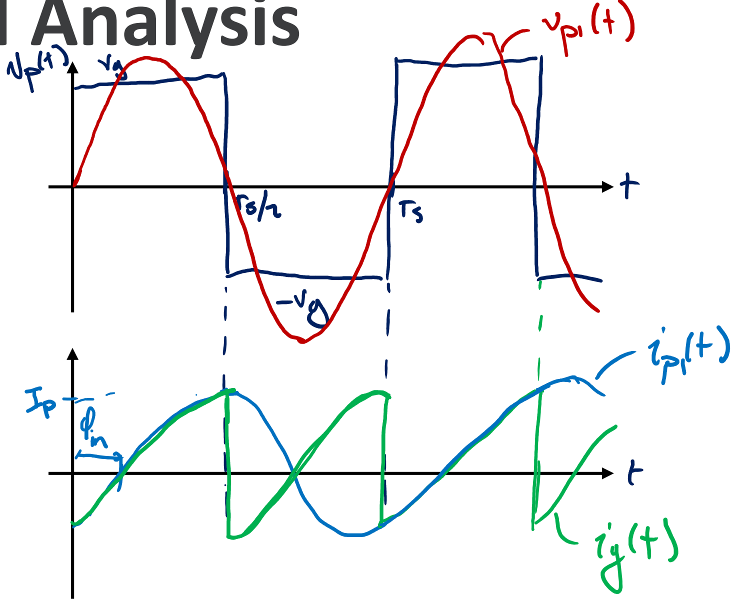
$$= 2\left(\frac{2}{T_s}\right)\int_0^{T_s/2} V_g \sin(2\pi f_s t)\,dt$$

$$= \frac{4}{T_s}V_g\int_0^{\pi}\sin\theta\,\frac{1}{2\pi f_s}\,d\theta$$

$$= \frac{4}{T_s}V_g\,\frac{1}{2\pi f_s}\left[-\cos\theta\right]\Big|_0^{\pi}$$

$$= \frac{4}{T_s}V_g\,\frac{1}{2\pi f_s}(2) = \boxed{\frac{4}{\pi}V_g} = b_1$$

$\frac{4}{\pi} \approx 1.27$



# Input Current

say $i_{p1}(t) = I_p \sin(2\pi f_s t - \phi_{in})$

then the DC input current is

$$I_g = \langle i_g(t) \rangle \Big|_{T_s} = \frac{2}{T_s} \int_0^{T_s/2} i_{p1}(t)\, dt$$

$$= \frac{2}{T_s} \int_0^{T_s/2} I_p \sin(2\pi f_s t - \phi_{in})\, dt$$

$$= \frac{2}{T_s} I_p \int_{-\phi_{in}}^{\pi-\phi_{in}} \sin(\theta) \frac{1}{2\pi f_s}\, d\theta$$

$$= \frac{2}{T_s} I_p \frac{1}{2\pi f_s} \left[ -\cos(\theta) \right] \Big|_{-\phi_{in}}^{\pi-\phi_{in}}$$

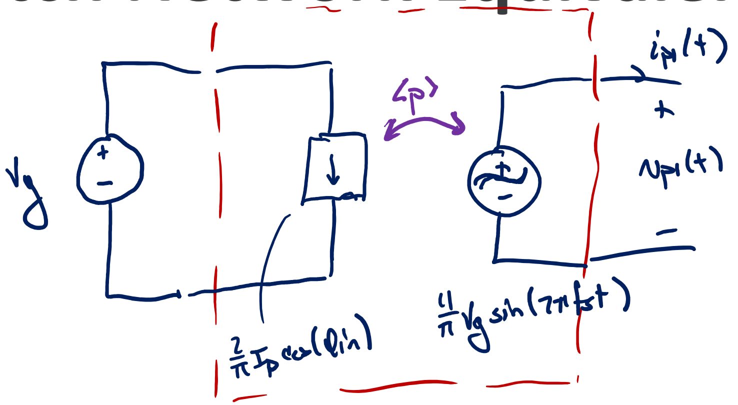
$$= \frac{2}{T_s} I_p \frac{1}{2\pi f_s} 2\cos(\phi_{in})$$

$$\boxed{I_g = \frac{2}{\pi} I_p \cos(\phi_{in})}$$

$\theta = 2\pi f_s t - \phi_{in}$

$d\theta = 2\pi f_s\, dt$

# Switch Network Equivalent Circuit




$$P_g = V_g I_g = V_g \frac{2}{\pi} I_p \cos(\varphi_{in})$$

$$P_{ac} = \langle i_{p1} \cdot v_{p1} \rangle_{T_s}$$

$$= \frac{1}{T_s} \int_0^{T_s} I_p \sin(2\pi f_s t - \varphi_{in}) \frac{4}{\pi} V_g \sin(2\pi f_s t)\, dt$$

Phasor model

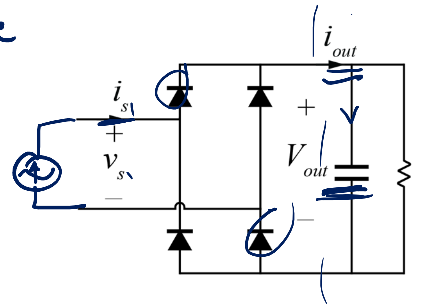
$$= \quad I_{p1} = I_p \angle -\varphi_{in}$$

$$V_{p1} = \frac{4}{\pi} V_g \angle 0$$

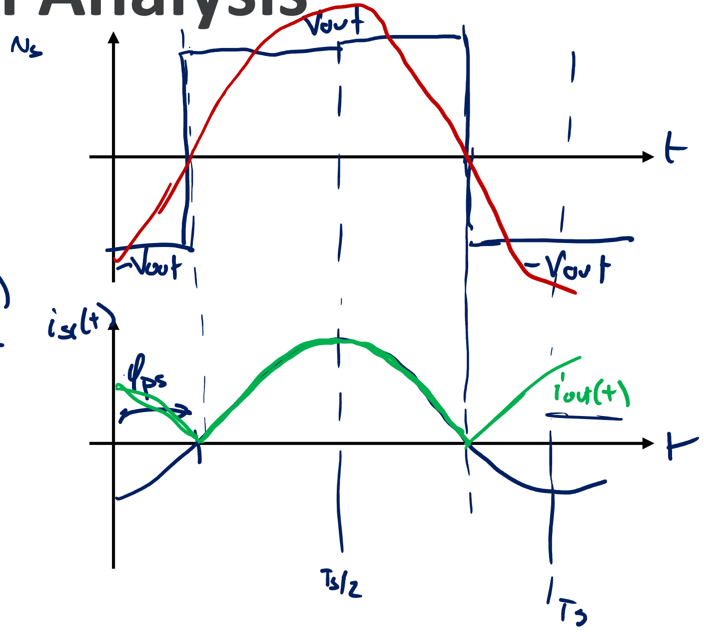
$$P = \frac{1}{2} I_p \frac{4}{\pi} V_g \cdot \cos(\varphi_{in})$$ ✓

# Diode Rectifier Sinusoidal Analysis

Assume




$i_{s1}(t) =$
$I_s \sin(2\pi f_s t - \varphi_{ps})$



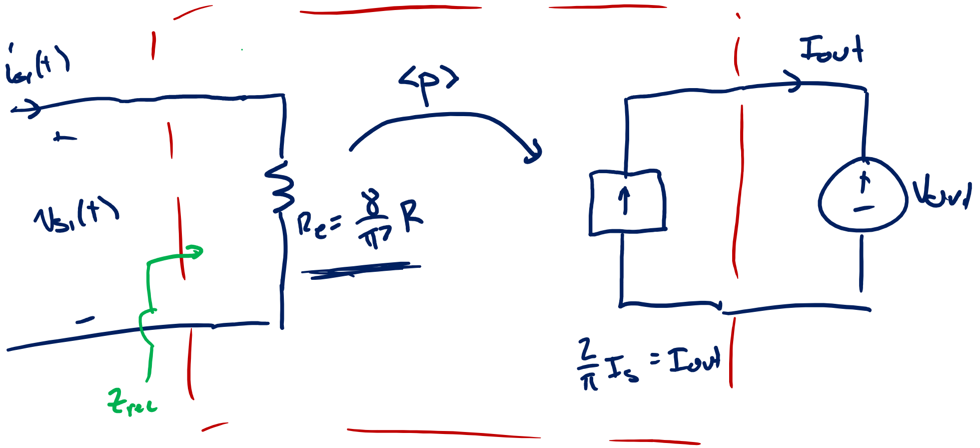

$v_{s1}(t) = \frac{4}{\pi} V_{out} \sin(2\pi f_s t - \varphi_{ps})$

(same derivation as inverter)

$$I_{out} = \langle i_{out} \rangle \big|_{T_s} = \boxed{\frac{2}{\pi} I_s = I_{out}}$$

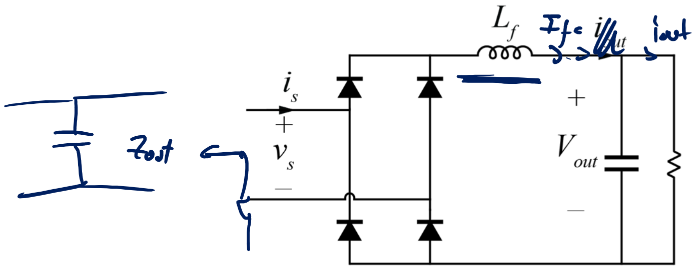
$$V_{out} = I_{out} R = \frac{2}{\pi} I_s R$$

# Diode Rectifier Equivalent Circuit



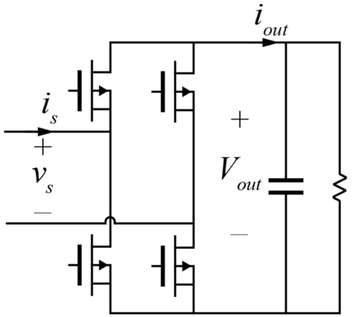

$$Z_{rec} = \frac{v_{s1}}{i_{s1}} = \frac{\frac{4}{\pi} V_{out} \sin(2\pi f_s t - \phi_{ps})}{I_s \sin(2\pi f_s t - \phi_{ps})} = \frac{\frac{4}{\pi} V_{out}}{I_s} = \frac{\frac{4}{\pi} V_{out}}{\frac{\pi}{2} I_{out}} = \frac{8}{\pi^2} \frac{V_{out}}{I_{out}} = \frac{8}{\pi^2} R$$

# Other Implementations




large $L_f \rightarrow I_f \approx$ constant

$i_s(t) =$

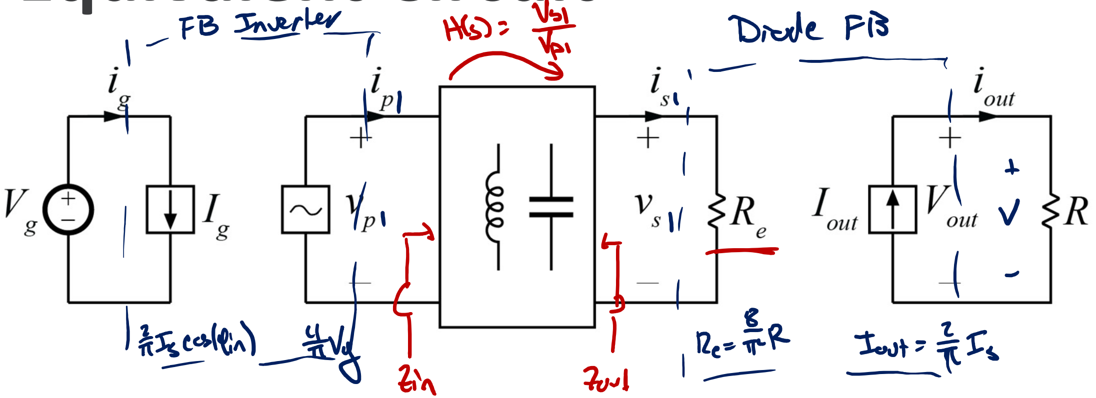

Synchronous Rectifier

$\varphi_{i_s - v_s}$ is not necessarily zero

$Z_e = R_e' + jX_e$

can also control duty cycle

# Complete Equivalent Circuit




For FB Inverter, FB Diode Rectifier

$$M = \frac{V}{V_g} = \frac{V_{out}}{I_{out}} \cdot \frac{I_{out}}{I_s} \cdot \frac{I_s}{V_s} \cdot \frac{V_s}{V_p} \cdot \frac{V_p}{V_g}$$

$$= R \cdot \frac{2}{\pi} \cdot \frac{\pi^2}{8} \frac{1}{R} \cdot \|H(s)\| \cdot \frac{4}{\pi}$$

$$M = \|H(s)\|$$