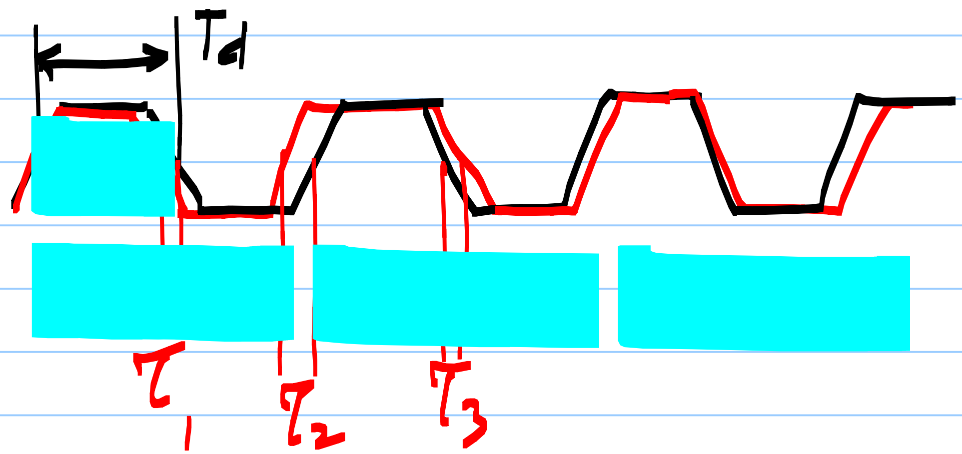
EE6322 Vco phase noise 19/2/2018



noise less

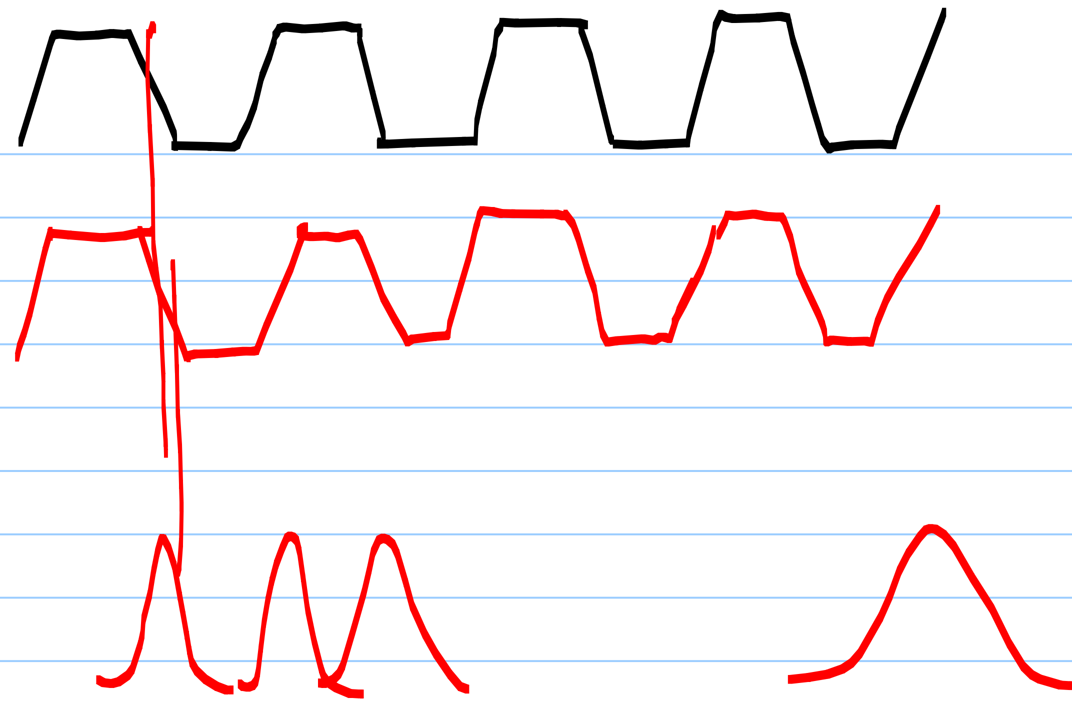
$\tau_k \cdot \frac{2\pi}{T_s}$: phase noise in radians

Nominal half period : T_d (delay of the chain)

Actual k^{th} half period : $T_d + (-1)^{k+1} \cdot \frac{v_n(nT_d)}{S'}$ ← slope

Nominal k^{th} edge : $k \cdot T_d$

Actual k^{th} edge : $kT_d +$

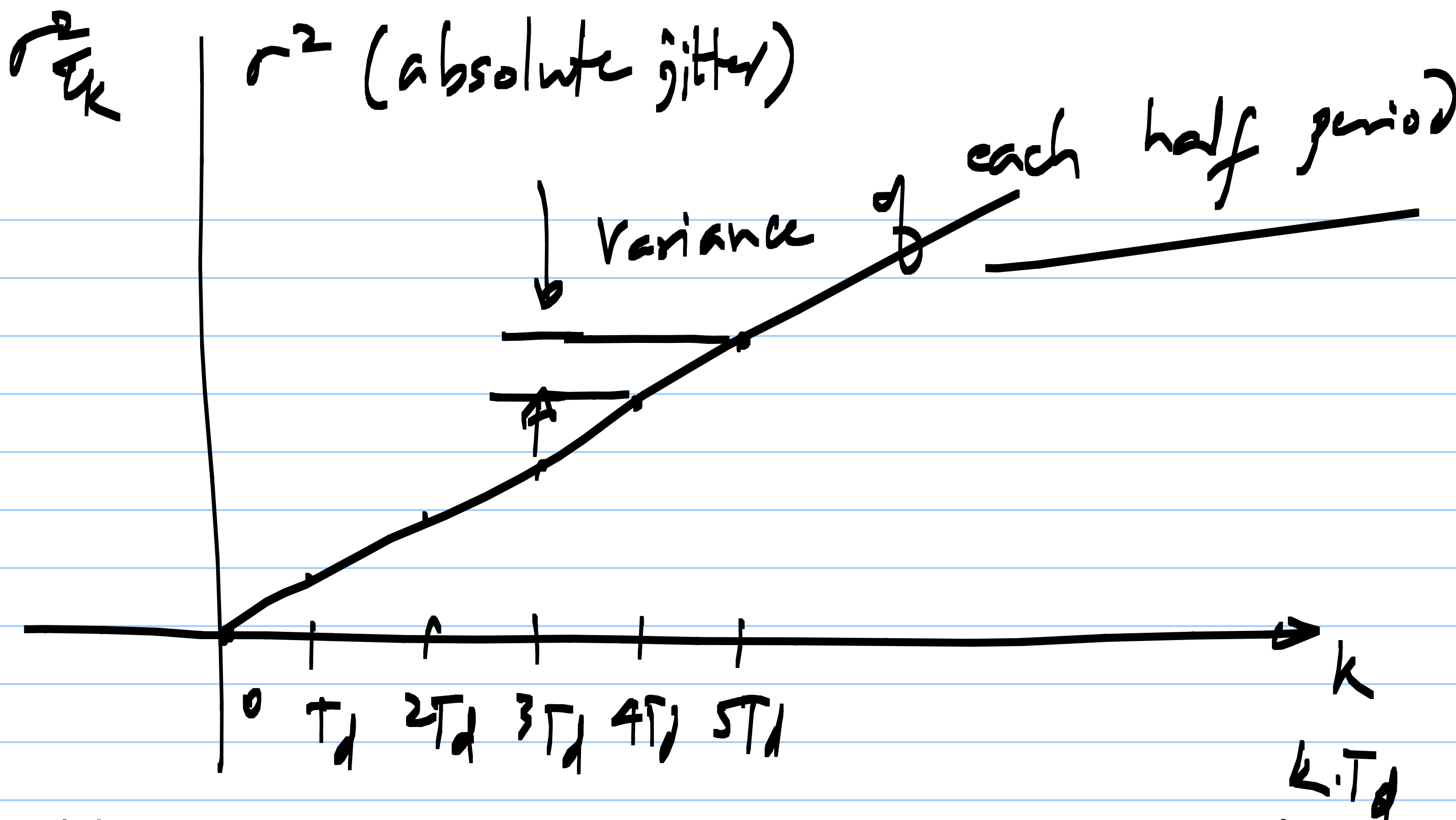


absolute jitter: edge timing compared to an ideal periodic clock (first edge synchronized)

$$y = \left[x_1 + x_2 + x_3 \cdots + x_N \right]$$

x_k : i.i.d std. dev. σ

std. dev. of $y = \sqrt{N} \cdot \sigma$



Absolute jitter variance increases linearly with time

(Half) Period jitter : constant variance (white)

\# 1st edge. $\underline{\text{1GHz osc.}}$

period = 1ns

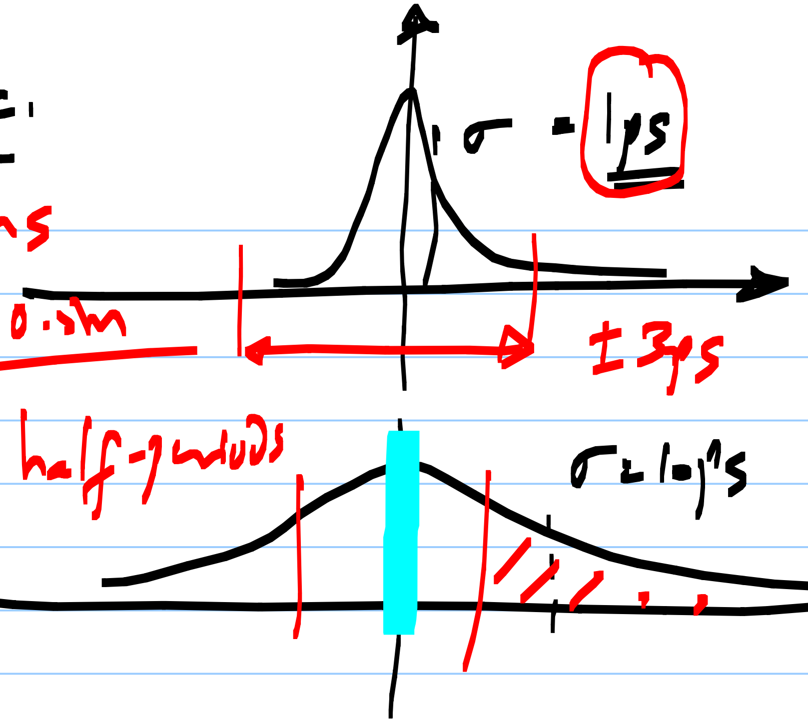
$\frac{1}{2}$ period = 0.5ns

100th edge

1 million half-periods

$\boxed{0.5\text{ms}}$

σ = 1ns



"Longitude" problem

$$\underbrace{\tau_k - \tau_{k-1}} = \frac{(-1)^{k+1} \cdot v_n(kT_0)}{s} = \frac{v_n'(kT_0)}{s}$$

[$v_n(kT_0)$ is white, $v_n'(kT_0)$ is also white]

$$\tau(z)\left(1 - z^{-1}\right) = \frac{v_n'(z)}{s}$$

$$\underset{\text{white}}{\frac{v_n'}{s}} \longrightarrow \boxed{\frac{1}{1-z^{-1}}} \longrightarrow \tau(z) \qquad \tau(z) = \frac{1}{1-z^{-1}} \frac{v_n'(z)}{s}$$

$$z = \exp\left(j\,2\pi f / 2f_0\right)$$

(f_0: oscillation freq.)

$$\tau(z) = \frac{1}{1 - z^{-1}} \frac{v_n'(z)}{s}$$

$$S_\tau(f) = \underbrace{S_v(f)}_{\text{Constant with freq.}} \cdot \frac{1}{s^2} \cdot \Bigg| \underbrace{\frac{1}{1 - \exp\left(-j\frac{\pi f}{f_0}\right)}}_{} \Bigg|^2$$

$$\left| j2 \cdot \sin\left(\frac{\pi f}{2f_0}\right) \cdot \exp\left(-j\frac{\pi f}{2f_0}\right) \right|^2$$

$$= S_v(f) \cdot \frac{1}{s^2} \cdot \frac{1}{4\sin^2 \frac{\pi f}{2f_0}}$$

Sampled noise process, white

$$S_T(f) = S_v(f) \cdot \frac{1}{S^2} \cdot \frac{1}{4 \sin^2 \frac{\pi f}{2 f_0}}$$

(const PSD from 0 to f_0)

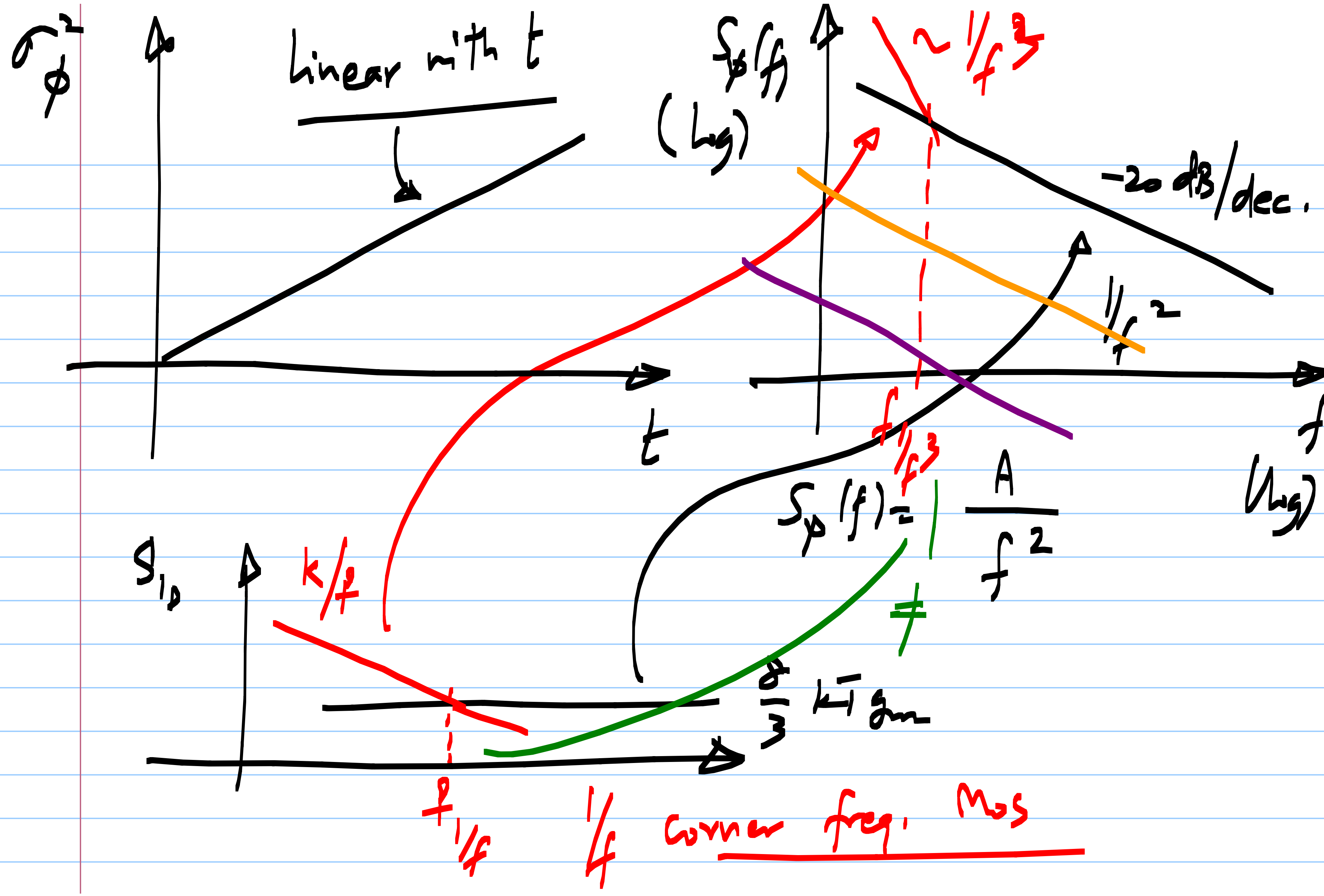
$$\simeq S_v(f) \cdot \frac{1}{S^2} \cdot \frac{(2f_0)^2}{4 \cdot (\pi f)^2}$$

$f \ll f_0$

$$= S_v(f) \cdot \frac{1}{S^2} \cdot \frac{1}{\pi^2} \cdot \left(\frac{f_0}{f}\right)^2$$

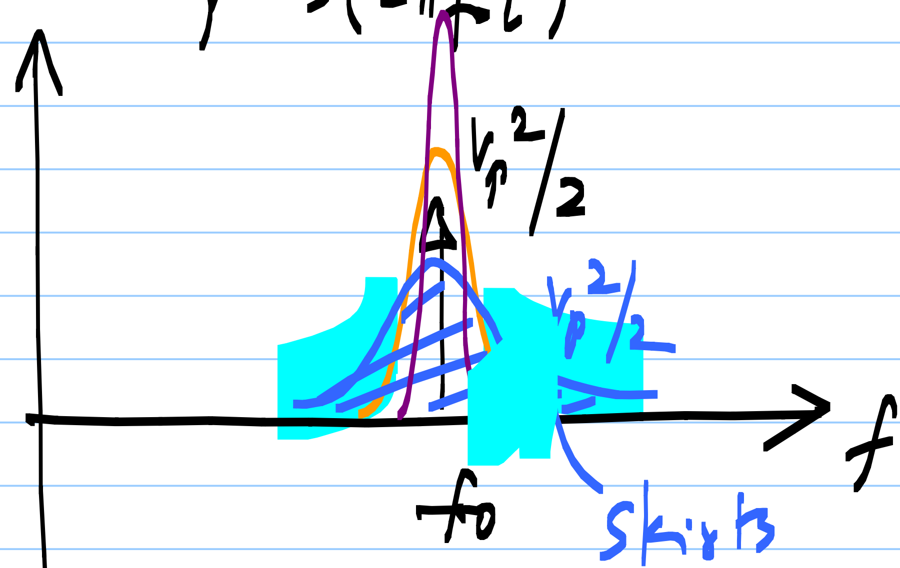
$$\phi_k = 2\pi f_0 \cdot T_k$$

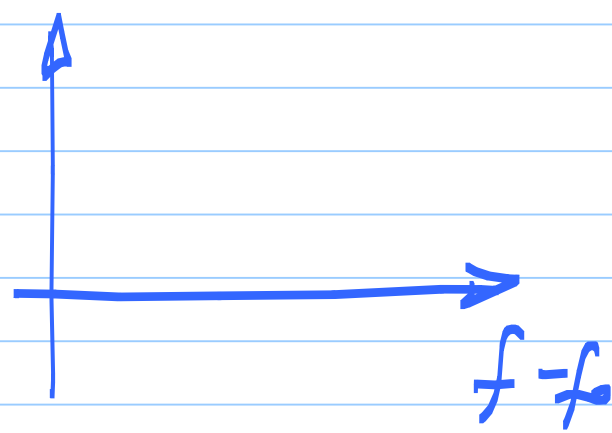
$$S_\phi(f) = S_v(f) \cdot \frac{1}{S^2} \cdot 4 \, f_0^4$$


σ_ϕ^2
linear with t
t
$S_\phi(f)$
(log)
$\sim 1/f^3$
-20 dB/dec.
$1/f^2$
f
(log)
f_{1/f^3}
$S_\phi(f) = \frac{A}{f^2}$
$\neq$
S_{I_D}
K/f
$\frac{8}{3} kT g_m$
$f_{1/f}$
1/f corner freq. MOS

ideal oscillator:

$V_p \cdot \cos(2\pi f t)$





$V_p \cos(2\pi f_0 t + \phi(t))$

phase noise

$V_p \cos(2\pi f_0 t) \cdot \cos(\phi(t))$

$- V_p \sin(\sin 2\pi f_0 t) \cdot \sin \phi(t)$

$\simeq V_p \cos(2\pi f_0 t)$

$- V_p \cdot \phi(t) \cdot \sin(2\pi f_0 t)$

$|f - f_0|$

$V_p \cos(2\pi f_0 t)$

$V_p \cos(2\pi f_0 t + \phi(t))$

$V_p \cdot \mathrm{sgn}\left(\cos 2\pi f_0 t + \phi(t)\right)$

$V_p \cdot \sum_{n: odd} \frac{4}{n\pi} \cos(2\pi n f_0 t)$

$\sum \frac{4}{n\pi} \cos(2\pi n f_0 t + n\phi(t))$