連続時間系フィルタの自動調整

参照フィルタを用いた周波数特性の自動調整

素子値の一様偏差の影響

$$T_0(s)=F[sC_i,\quad G_j]$$

一様偏差: $C_i \rightarrow k_C C_i \qquad G_j \rightarrow k_G G_j$

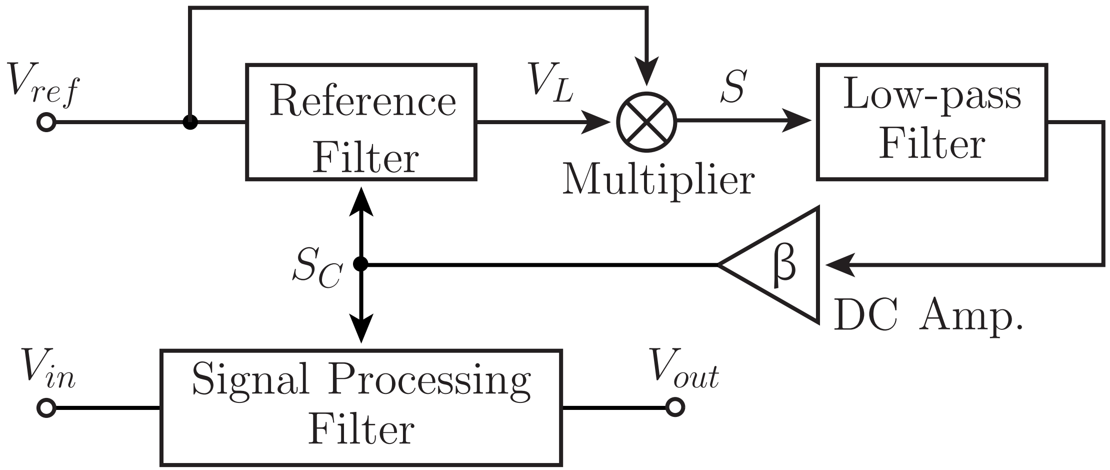
$$T(s)=F[sk_C C_i,\quad k_G G_j]$$

$\downarrow$ インピーダンス・スケーリング

$$T(s)=F\left[s\frac{k_C}{k_G}C_i,\quad G_j\right]=T_0\left(s\frac{k_C}{k_G}\right)$$

周波数スケーリング

周波数偏差自動調整回路

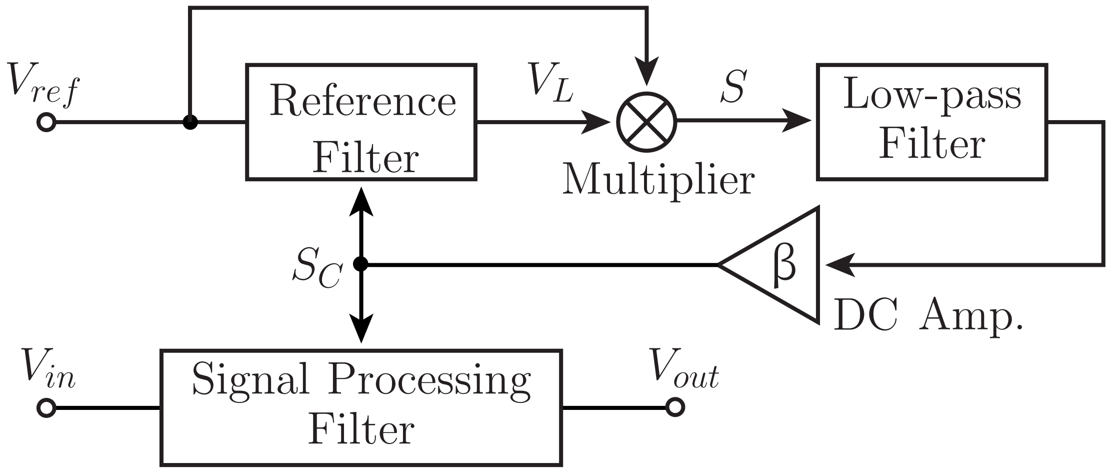


$$V_{ref}=V_m\sin\omega_{ref}t \qquad V_L=AV_m\sin(\omega_{ref}t+\theta)$$

$$S=M(V_{ref}\times V_L)=M\{V_m\sin\omega_{ref}t\times AV_m\sin(\omega_{ref}t+\theta)\}$$

$$=\frac{1}{2}MAV_m{}^2\{\cos\theta-\cos(2\omega_{ref}t+\theta)\}$$

$$\boxed{S_C=\frac{1}{2}\beta MAV_m{}^2\cos\theta}$$

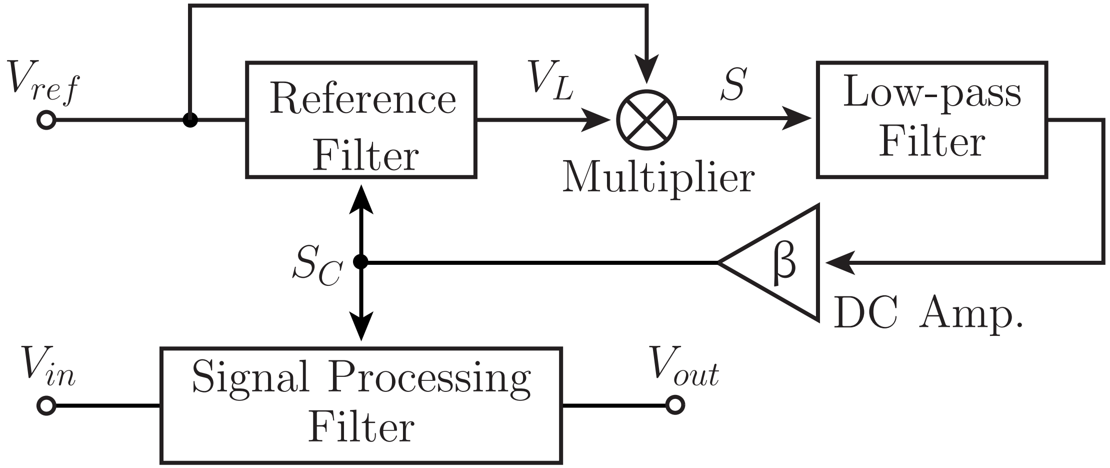


$$\boxed{S_C = \frac{1}{2}\beta M A {V_m}^2 \cos\theta}$$

$\beta \to \infty$:有限値に確定

$$\boxed{\cos\theta = \frac{2S_C}{\beta M A {V_m}^2}}$$

$$\boxed{\cos\theta \to 0}$$



参照用フィルタの伝達関数:

$$T_{L2}(s)=\frac{K\omega_0^{\ 2}}{s^2+\frac{\omega_0}{Q}s+\omega_0^{\ 2}}$$

$$\theta=-\tan^{-1}\frac{\omega_{ref}\,\omega_0}{Q(\omega_0^{\ 2}-\omega_{ref}^{\ \ 2})}$$

$$\theta=-90^\circ\rightarrow\omega_0=\omega_{ref}$$

参照用フィルタの素子偏差の割合

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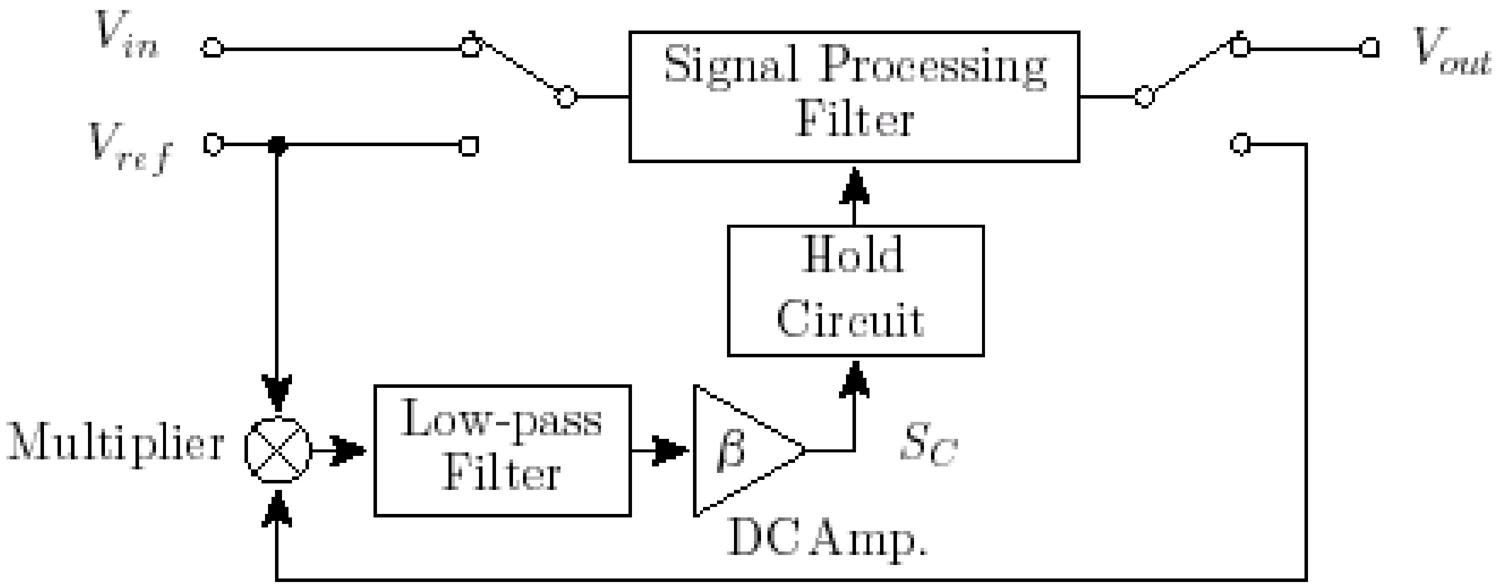
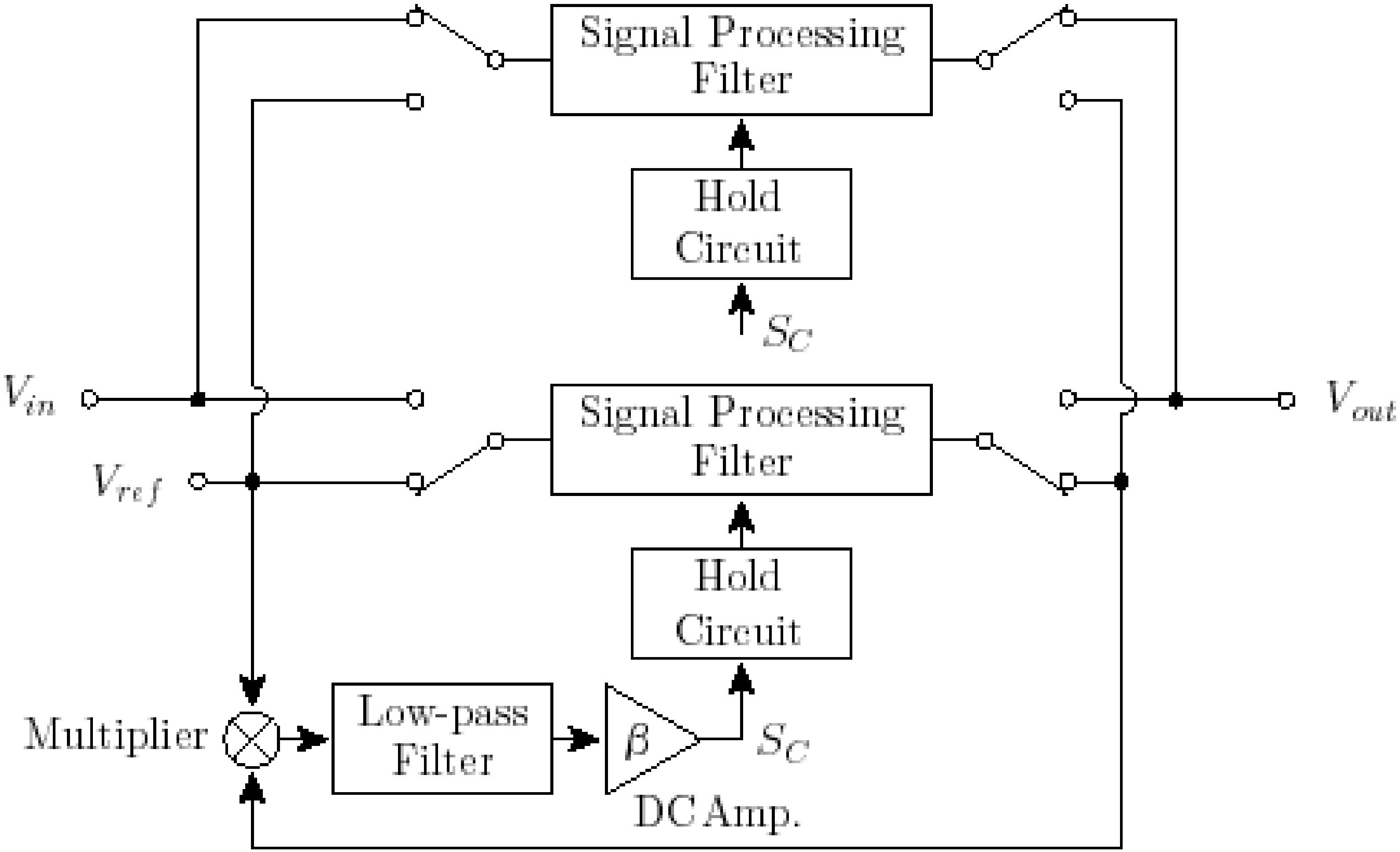
信号処理用フィルタの素子偏差の割合

参照フィルタを用いない周波数特性の自動調整

間欠型自動調整

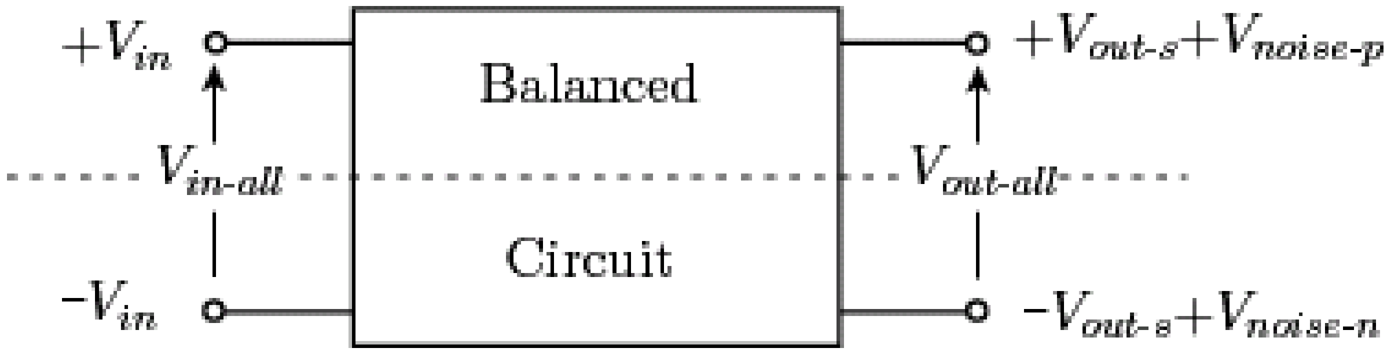


非間欠型自動調整



Signal Processing Filter
Hold Circuit
S_C
V_{in}
V_{ref}
Signal Processing Filter
Hold Circuit
V_{out}
Multiplier
Low-pass Filter
β
S_C
DC Amp.

Balanced-type structure



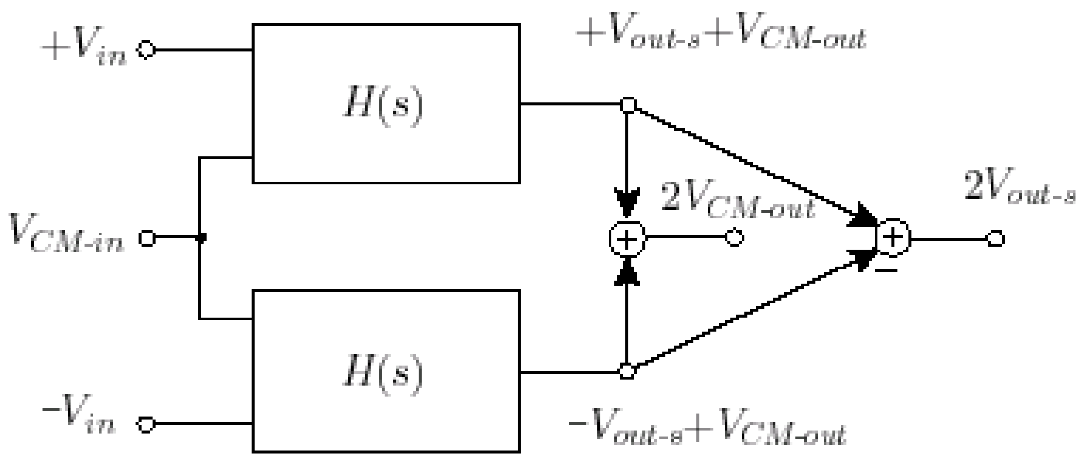
Symmetry Structure

$$V_{out\text{-}p} = +V_{out\text{-}s} + V_{noise\text{-}p}$$
$$V_{out\text{-}n} = -V_{out\text{-}s} + V_{noise\text{-}n}$$

$$V_{noise\text{-}p} = +V_{noise\text{-}d} + V_{noise\text{-}c}$$
$$V_{noise\text{-}n} = -V_{noise\text{-}d} + V_{noise\text{-}c}$$

$$\boxed{V_{out\text{-}all} = V_{out\text{-}p} - V_{out\text{-}n} = 2(V_{out\text{-}s} + V_{noise\text{-}d})}$$

直接型自動調整



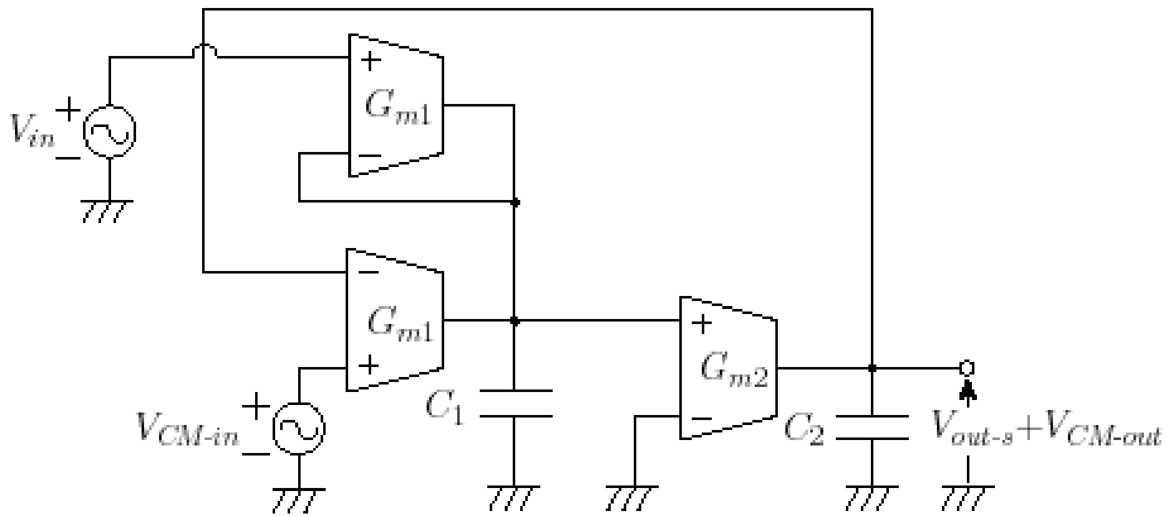
$$V_{out\text{-}p}=+V_{out\text{-}s}+V_{CM\text{-}out}=H_1(s)V_{in}+H_2(s)V_{CM\text{-}in})$$

$$V_{out\text{-}n}=-V_{out\text{-}s}+V_{CM\text{-}out}=-H_1(s)V_{in}+H_2(s)V_{CM\text{-}in}$$

$$\boxed{V_{out\text{-}p}-V_{out\text{-}p}=2H_1(s)V_{in}}$$

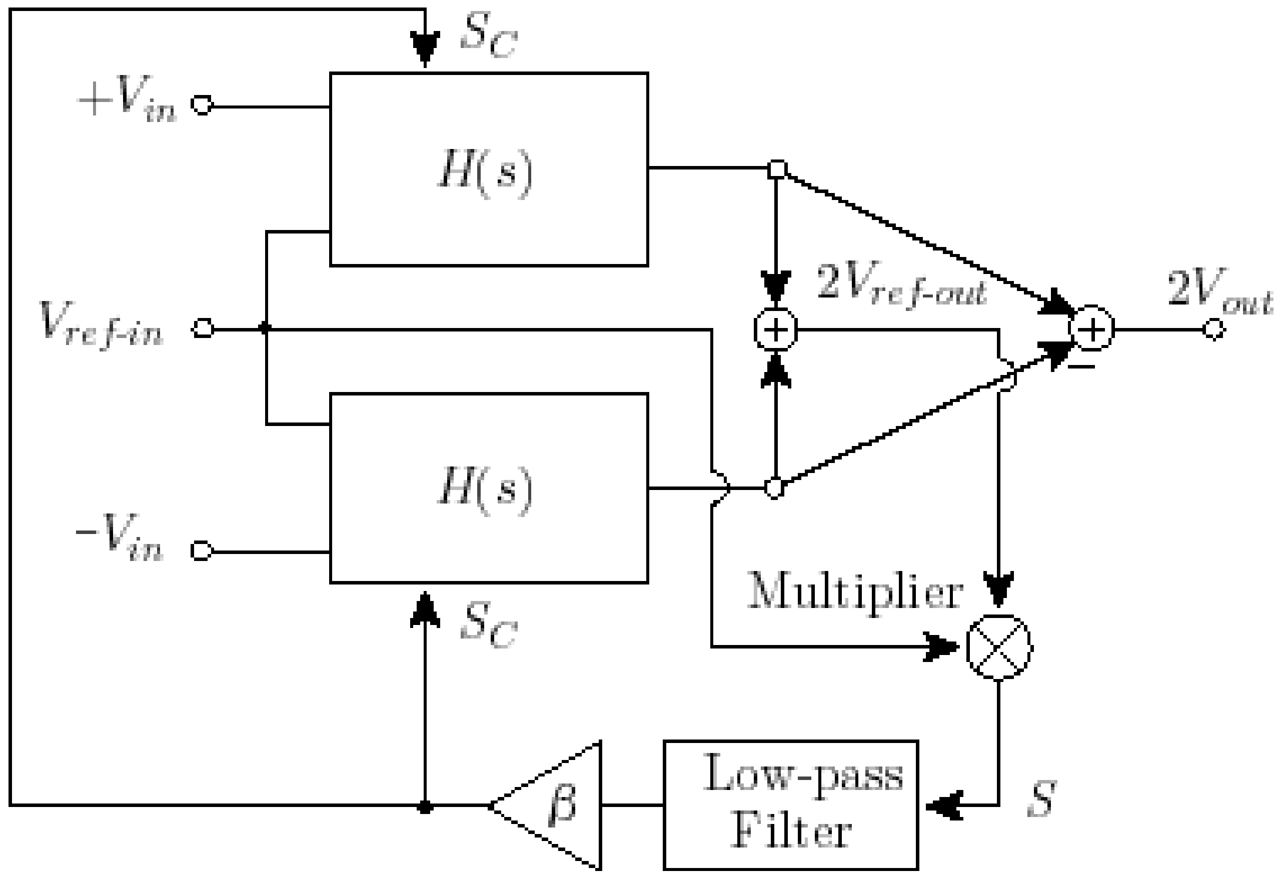
$$\boxed{V_{out\text{-}p}+V_{out\text{-}p}=2H_2(s)V_{CM\text{-}in}}$$

フィルタの構造



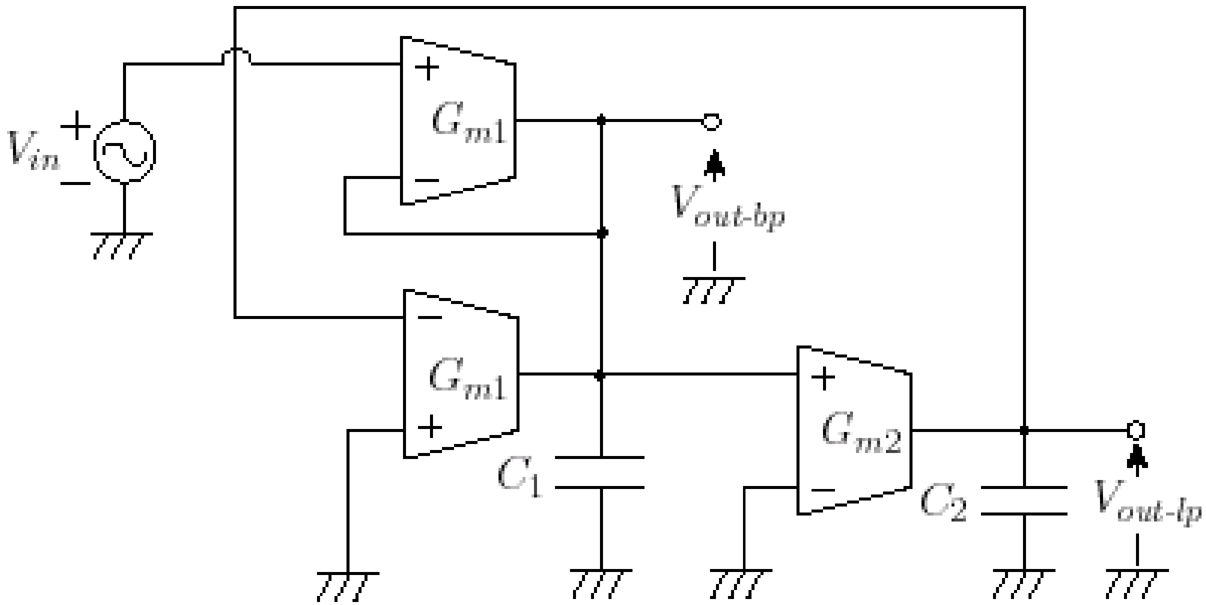
$$H_1(s)=H_2(s)=\frac{\dfrac{G_{m1}G_{m2}}{C_1C_2}}{s^2+\dfrac{G_{m1}}{C_1}s+\dfrac{G_{m1}G_{m2}}{C_1C_2}}$$

直接型自動調整の原理



S_C
$+V_{in}$
$H(s)$
$2V_{ref\text{-}out}$
$2V_{out}$
$V_{ref\text{-}in}$
$H(s)$
$-V_{in}$
Multiplier
S_C
β
Low-pass Filter
S

フィルタのクォリティファクタの自動調整



$$V_{out\text{-}bp} = \frac{\frac{G_{m1}}{C_1}s}{s^2 + \frac{G_{m1}}{C_1}s + \frac{G_{m1}G_{m2}}{C_1C_2}} V_{in} = \frac{F_1(s)}{1+F_1(s)+F_1(s)F_2(s)} V_{in}$$

積分回路の特性： $F_i(s) = a_i \frac{\omega_t}{s} e^{s\tau(\omega)}$

$$V_{out\text{-}bp} = \frac{F_1(s)}{1+F_1(s)+F_1(s)F_2(s)} V_{in} \qquad F_i(s) = a_i \frac{\omega_t}{s} e^{s\tau(\omega)}$$

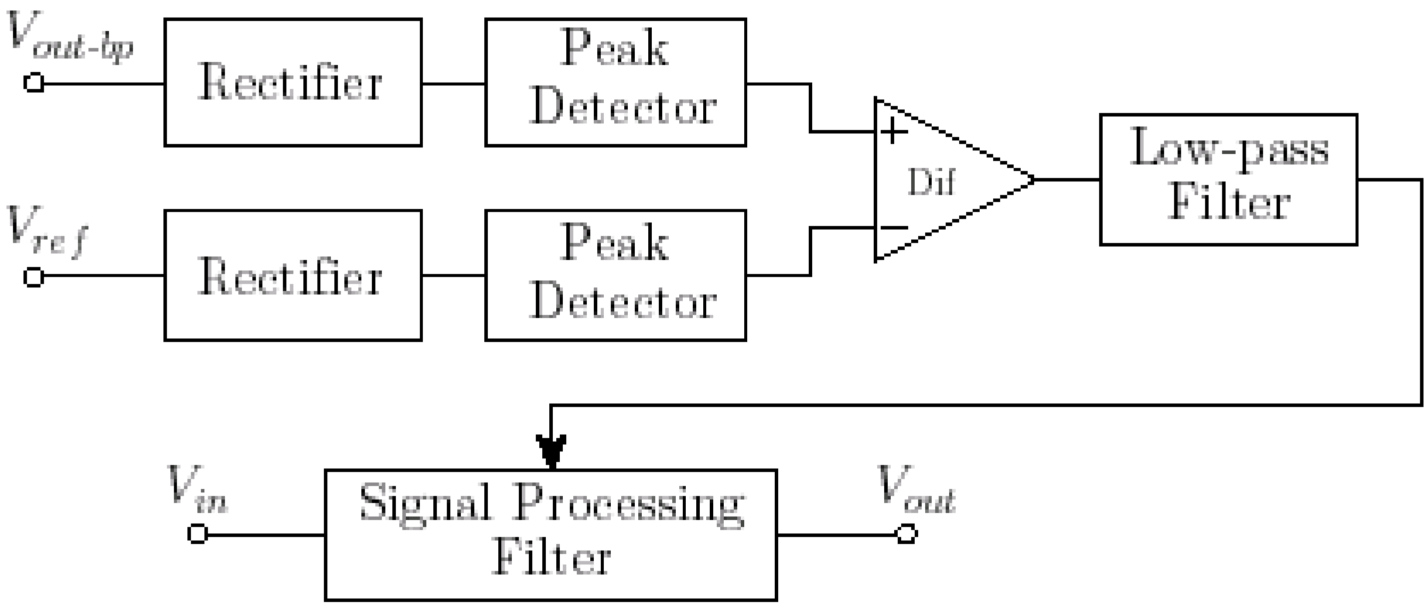
$$T_{bp}(s) = \frac{H_0 \frac{\omega_0}{Q} s}{s^2 + \frac{\omega_0}{Q} s + \omega_0{}^2}$$

$$\boxed{\omega_a \approx \omega_0} \qquad \boxed{Q_a \approx \frac{Q}{1-2Q\,\omega_0\tau}} \qquad \boxed{H_a \approx \frac{H_0}{1-2Q\,\omega_0\tau}}$$

$$Q \approx \frac{Q_a}{2Q_a\omega_0\tau+1} \quad \Rightarrow \quad H_a \approx H_0(2Q_a\omega_0\tau+1) \qquad \boxed{\tau(\omega) \approx \tau(\omega_0)}$$

クォリティファクタの自動調整の原理

ω_0: V_{ref}の角周波数



$\boxed{\text{例題}}$

$\boxed{\text{参照用低域通過フィルタ}}$

$$T_{L2}(s)=\frac{K{\omega_0}^2}{s^2+\frac{\omega_0}{Q}s+{\omega_0}^2}$$

$K=1,\quad \omega_0=2\pi\times1000\,\mathrm{rad/s},\quad Q=5$

$\boxed{\text{乗算回路}}$ $M=1\mathrm{V}^{-1}$ $\boxed{\text{直流増幅回路}}$ $\beta=100$

$\boxed{\text{参照入力信号振幅}}$ $V_m=0.2\mathrm{V}$

$$cos\theta=\frac{2S_C}{\beta MA{V_m}^2}$$

$\boxed{A=?}$ $\boxed{S_C=?}$

$$\boxed{\omega_{ref} \approx \omega_0 \text{とすれば}}$$

$$A = \left|T_{L2}(j\omega_{ref})\right| = \left|\frac{K\omega_0{}^2}{-\omega_{ref}{}^2 + j\dfrac{\omega_0}{Q}\omega_{ref} + \omega_0{}^2}\right| \approx Q$$

$$\boxed{g_m = \alpha S_C \text{かつ} g_m \propto \omega_0 \text{とすれば}}$$

$$\omega_{00} \rightarrow S_{C0}$$

$$\omega_0 \rightarrow S_C$$

$$\boxed{\frac{\omega_0}{\omega_{00}} = \frac{S_C}{S_{C0}}}$$

$$\boxed{S_C = \frac{\omega_0}{\omega_{00}} S_{C0}}$$

$$M=1\mathrm{V}^{-1} \qquad \beta=100 \qquad V_m=0.2\mathrm{V} \qquad A\approx Q=5$$

$$\omega_{00}=2\pi\times 800\,\mathrm{rad/s},\quad S_{C0}=0.1\mathrm{V}\rightarrow S_C=0.125\mathrm{V}$$

$$\cos\theta=\frac{2S_C}{\beta MAV_m{}^2}=0.03125 \qquad \theta=-88.2\text{度}$$

$$\theta=-\tan^{-1}\frac{\omega_{ref}\,\omega_0}{Q(\omega_0{}^2-\omega_{ref}{}^2)}$$

$$\boxed{\omega_0=\frac{-1+\sqrt{1+4Q^2\tan^2\theta}}{2Q\tan\theta}\omega_{ref}=0.992\,\omega_{ref}}$$