2-Charge-Pump Boosted PLL w/Resistor Switching

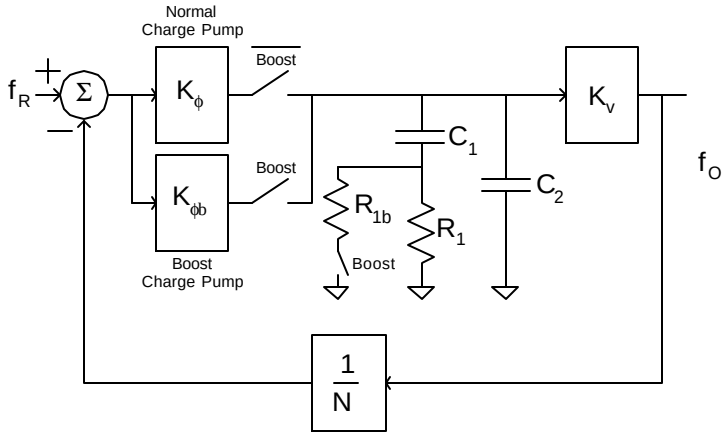


Fig. 2: 3rd-Order PLL with Boosted Charge Pump and Switched-Resistor Loop Filter.

useful functions and identities
Units
Constants

Table of Contents

Introduction

When switches are used as part of the loop filter one can think of many topologies for maintaining stability while boosting the bandwidth. For example, the resistor can be switched or the capacitor switched. By far, the most elegant scheme is to switch the resistor from one value to another. This method has no breakdown problems and the resistance of the switch can be incorporated into the loop filter resistor. The phase margin remains unchanges in boos. and unboosted modes, with no penalty in spurious response, and big improvements in settling response. This method also has the advantages of introducing very little extra charge into the loop, so the switch to normal mode results in a much smaller transient than from switching capacitors.

This method is described in [NS1000]. The NS1000 applies the technique for a doubling of the loop bandwidth, while the equations here are generalized to any desired boost in bandwidth. The application note references several patents and articles[Shepard][Sharoni][Swisher][Arnold][Keese][Barker], which pre-date the application note.

Inputs

$B := 10$ Desired frequency boost

$f_{step} := 25MHz$ Maximum output frequency step

$f_o := 1GHz$ Output Frequency

$f_r := 1MHz$ Reference frequency

$f_{acc} := 1kHz$ Acceptable frequency error for settling

$PM_{des} := 60deg$ Desired phase margin

$I := 200\mu A$ Charge pump current

$K_v := 2\cdot\pi\cdot 15\cdot\frac{MHz}{volt}$ VCO Gain

$num := 100$ $i := 1..num$ Number of points for plotting

$f_u := 10kHz$ $\omega_u := 2\cdot\pi\cdot f_u$ Desired unity gain bandwidth

Preliminary Calculations

$N := \frac{f_o}{f_r}$ $N = 1\times 10^3$ Divider ratio

$K_\phi := \frac{I}{2\cdot\pi}$ Tri-state charge pump gain

Loop Filter Design

To solve for the loop filter components with resistor boost, we first solve for the loop filter components in non-boost mode, as done in another report.

$$\omega u\_\omega z(PM) := \left| \begin{array}{l} wu\_wz \leftarrow 4 \\ root\left[\left(atan(wu\_wz) - atan\left(\frac{1}{wu\_wz}\right)\right)\cdot\frac{180\cdot deg}{\pi\cdot rad} - PM,\ wu\_wz\right] \end{array} \right.$$

$wu\_wz := \omega u\_\omega z(PM_{des})$ $\quad wu\_wz = 3.732$

$$C_{2rb} := \frac{K_\phi \cdot K_v}{\omega_u^{\,2}\cdot N\cdot wu\_wz} \qquad C_{2rb} = 0.204\,nF$$

$$C_{1rb} := \frac{K_\phi \cdot K_v \cdot \left(wu\_wz^{\,2} - 1\right)}{\omega_u^{\,2}\cdot N\cdot wu\_wz} \qquad C_{1rb} = 2.632\,nF$$

$$R_{1rb} := \frac{\omega_u \cdot N\cdot wu\_wz^{\,2}}{K_\phi \cdot K_v \cdot \left(wu\_wz^{\,2} - 1\right)} \qquad R_{1rb} = 22.564\,k\Omega$$

In boost mode we solve the following equations using the boosted current and parallel resistor combination

$$R1bparaR1 = \frac{R_{1b}\cdot R_1}{R_{1b} + R_1}$$

$$\omega_{ub} = \sqrt{\frac{wu\_wz\cdot K_{\phi b}\cdot K_v}{N\cdot(C_1 + C_2)}}$$

$$\omega_{ub} = \frac{C_1 + C_2}{R1bparaR1\cdot C_1\cdot C_2}\cdot\frac{1}{wu\_wz}$$

$$\omega_{ub} = \frac{wu\_wz}{R1bparaR1\cdot C_1}$$

Substituting in the expressions for C_1 and C_2 we get the following relations:

$$\frac{K_{\phi b}}{K_\phi} = \left(\frac{\omega_{ub}}{\omega_u}\right)^2 = B^2$$

$$\frac{R1bparaR1}{R_1} = \frac{\omega_{ub}}{\omega_u} = B$$

Using these expressions and given B, the boosted bandwidth we get the following values for the boosted charge pump gain and parallel boost resistor, R_{1b}.

$$R_{1b} := \frac{R_{1rb}}{B - 1} \qquad R_{1b} = 2.507\,k\Omega$$

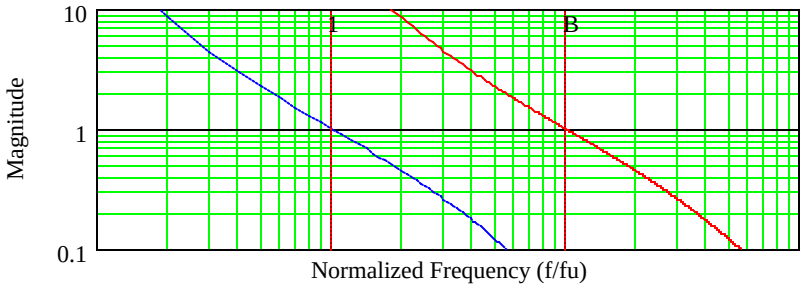
$$K_{\phi b} := B^2\cdot K_\phi \qquad K_{\phi b} = 3.183\,mA$$

An important note on using the resistor boost method is that the current boost requires the square of the desired bandwidth boost. This allows the PLL consume more current than other methods (but only during boost), which enhances the settling time by greatly reducing the slewing response for a given bandwidth boost. A plot of the

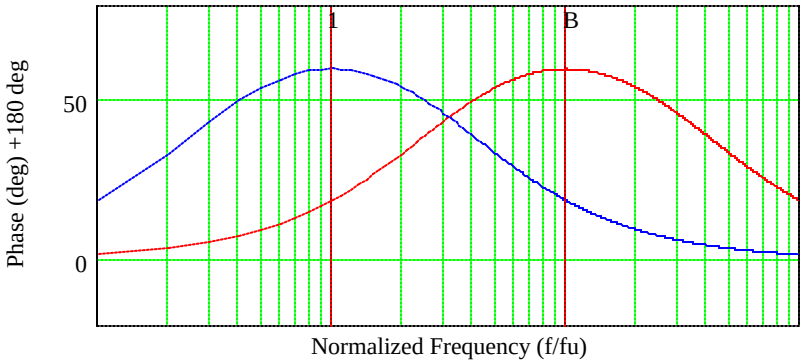
frequency responses in boost and non boost mode are given below:

$$GHb(s) := K_{\phi b} \cdot \frac{1}{s^2} \cdot \frac{\frac{R_{1rb} \cdot R_{1b}}{R_{1rb} + R_{1b}} \cdot C_{1rb} \cdot s + 1}{1 + \frac{R_{1rb} \cdot R_{1b}}{R_{1rb} + R_{1b}} \cdot \frac{C_{1rb} \cdot C_{2rb}}{C_{1rb} + C_{2rb}} \cdot s} \cdot \frac{K_v}{C_{1rb} + C_{2rb}} \cdot \frac{1}{N}$$

$$GH(s) := K_{\phi} \cdot \frac{1}{s^2} \cdot \frac{R_{1rb} \cdot C_{1rb} \cdot s + 1}{1 + R_{1rb} \cdot \frac{C_{1rb} \cdot C_{2rb}}{C_{1rb} + C_{2rb}} \cdot s} \cdot \frac{K_v}{C_{1rb} + C_{2rb}} \cdot \frac{1}{N}$$



wu_wz = 3.732 B = 10 $PM_{des} = 60\,deg$



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