CEM3350 Analysis

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1 Introduction

A verbose but hopefully useful and correct analysis of the CEM3350 and AS3350 VCF IC. An input can be sent to multiple places within the circuit to obtain different responses and gains. Either a LowPass/BandPass response or a BandPass/HighPass response can be created. The input can also be sent to a fixed or variable gain input or some mix of the two. This will control the level of the output as the Q increases.

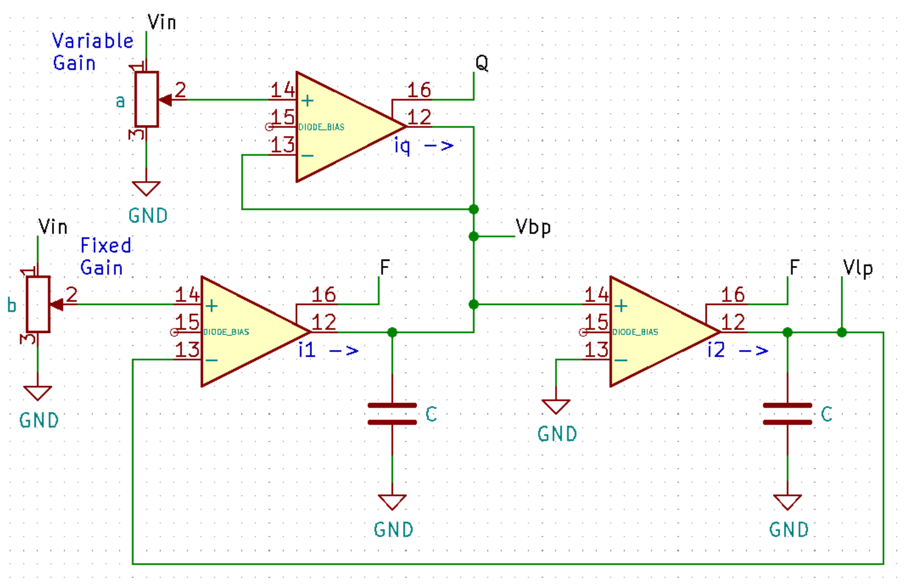

Figure 1: LowPass/BandPass configuration

1.1 Notations

F is the the frequency control variable

Q is the the Q control variable

a is the variable gain input scaling factor

b is the fixed gain input scaling factor

2 LowPass/BandPass Configuration

$$iq = Q(aV_{in} - V_{bp}) \tag{1}$$

$$i1 = F(bV_{in} - V_{lp}) \tag{2}$$

$$i2 = FV_{bp} \tag{3}$$

$$\hat{V}_{bp} = \frac{\hat{I}_1 + \hat{I}_q}{sC} \tag{4}$$

$$\hat{V}_{lp} = \frac{\hat{I}_2}{sC} \tag{5}$$

Simplify Vbp into terms of Vlp and Vin.

$$\begin{aligned}
\hat{V}_{bp} &= \frac{\hat{I}_1 + \hat{I}_q}{sC} \\
sC\hat{V}_{bp} &= \hat{I}_1 + \hat{I}_q \\
sC\hat{V}_{bp} &= Fb\hat{V}_{in} - F\hat{V}_{lp} + Qa\hat{V}_{in} - Q\hat{V}_{bp} \\
sC\hat{V}_{bp} + Q\hat{V}_{bp} &= Fb\hat{V}_{in} - F\hat{V}_{lp} + Qa\hat{V}_{in} \\
\hat{V}_{bp}(sC + Q) &= \hat{V}_{in}(Fb + Qa) - F\hat{V}_{lp}
\end{aligned}$$

$$\hat{V}_{bp} = \frac{\hat{V}_{in}(Fb + Qa) - F\hat{V}_{lp}}{sC + Q} \tag{6}$$

Get Vlp in terms of Vin and calculate Low Pass transfer function.

$$\hat{V}_{lp} = \frac{\hat{I}_2}{sC}$$
$$\hat{V}_{lp} = \frac{F\hat{V}_{bp}}{sC}$$
$$sC\hat{V}_{lp} = F\hat{V}_{bp}$$
$$sC\hat{V}_{lp} = \frac{\hat{V}_{in}(F^2b + FQa) - F^2\hat{V}_{lp}}{sC + Q}$$
$$\hat{V}_{lp}(s^2C^2 + sCQ) = \hat{V}_{in}(F^2b + FQa) - F^2\hat{V}_{lp}$$
$$\hat{V}_{lp}(s^2C^2 + sCQ) + F^2\hat{V}_{lp} = \hat{V}_{in}(F^2b + FQa)$$
$$\hat{V}_{lp}(s^2C^2 + sCQ + F^2) = \hat{V}_{in}(F^2b + FQa)$$
$$\frac{\hat{V}_{lp}}{\hat{V}_{in}} = \frac{F^2b + FQa}{s^2C^2 + sCQ + F^2}$$
$$= \frac{b + a\frac{Q}{F}}{s^2(\frac{C}{F})^2 + s\frac{C}{F}\frac{Q}{F} + 1}$$
$$H(s) = \frac{b + a\frac{Q}{F}}{\frac{s^2}{(\frac{F}{C})^2} + 2\frac{s}{\frac{F}{C}}\frac{Q}{2F} + 1} \tag{7}$$

Calculate Band Pass transfer function.

$$\hat{V}_{bp} = \frac{\hat{V}_{in}(Fb + Qa) - F\hat{V}_{lp}}{sC + Q}$$
$$\hat{V}_{bp}(sC + Q) = \hat{V}_{in}(Fb + Qa) - F\hat{V}_{lp}$$
$$\hat{V}_{bp}(sC + Q) = \hat{V}_{in}(Fb + Qa) - \frac{F^2\hat{V}_{bp}}{sC}$$
$$\hat{V}_{bp}(s^2C^2 + sCQ) = sC\hat{V}_{in}(Fb + Qa) - F^2\hat{V}_{bp}$$
$$\hat{V}_{bp}(s^2C^2 + sCQ) + F^2\hat{V}_{bp} = sC\hat{V}_{in}(Fb + Qa)$$
$$\hat{V}_{bp}(s^2C^2 + sCQ + F^2) = sC\hat{V}_{in}(Fb + Qa)$$
$$\frac{\hat{V}_{bp}}{\hat{V}_{in}} = \frac{sC(Fb + Qa)}{s^2C^2 + sCQ + F^2}$$
$$= \frac{s\frac{C}{F^2}(Fb + Qa)}{s^2\frac{C^2}{F^2} + s\frac{CQ}{F^2} + 1}$$
$$= \frac{s\frac{C}{F}(b + \frac{Q}{F}a)}{s^2(\frac{C}{F})^2 + s\frac{Q}{F}\frac{C}{F} + 1}$$
$$H(s) = \frac{s\frac{C}{F}(b + \frac{Q}{F}a)}{\frac{s^2}{(\frac{F}{C})^2} + 2\frac{s}{\frac{F}{C}}\frac{Q}{2F} + 1} \tag{8}$$

3 With Q Enhancement

The Q enhancement is just feeding a specific amount of the BandPass output back into the input.

3.1 Notations

F is the the frequency control variable

Q is the the Q control variable

x is the the Q enhancement feedback gain

a is the variable gain input scaling factor

b is the fixed gain input scaling factor

$$iq = Q(aV_{in} - V_{bp}) \tag{9}$$

$$i1 = F(bV_{in} + xV_{bp} - V_{lp}) \tag{10}$$

$$i2 = FV_{bp} \tag{11}$$

$$\hat{V}_{bp} = \frac{\hat{I}_1 + \hat{I}_q}{sC} \tag{12}$$

$$\hat{V}_{lp} = \frac{\hat{I}_2}{sC} \tag{13}$$

Simplify Vbp into terms of Vlp and Vin.

$$\begin{aligned}
\hat{V}_{bp} &= \frac{\hat{I}_1 + \hat{I}_q}{sC} \\
sC\hat{V}_{bp} &= \hat{I}_1 + \hat{I}_q \\
sC\hat{V}_{bp} &= Fb\hat{V}_{in} + Fx\hat{V}_{bp} - F\hat{V}_{lp} + Qa\hat{V}_{in} - Q\hat{V}_{bp} \\
sC\hat{V}_{bp} + Q\hat{V}_{bp} - Fx\hat{V}_{bp} &= Fb\hat{V}_{in} - F\hat{V}_{lp} + Qa\hat{V}_{in} \\
\hat{V}_{bp}(sC + Q - Fx) &= \hat{V}_{in}(Fb + Qa) - F\hat{V}_{lp}
\end{aligned}$$

$$\hat{V}_{bp} = \frac{\hat{V}_{in}(Fb + Qa) - F\hat{V}_{lp}}{sC + Q - Fx} \tag{14}$$

Get Vlp in terms of Vin and calculate Low Pass transfer function.

$$
\begin{aligned}
\hat{V}_{lp} &= \frac{\hat{I}_2}{sC} \\
\hat{V}_{lp} &= \frac{F\hat{V}_{bp}}{sC} \\
sC\hat{V}_{lp} &= F\hat{V}_{bp} \\
sC\hat{V}_{lp} &= \frac{\hat{V}_{in}(F^2b + FQa) - F^2\hat{V}_{lp}}{sC + Q - Fx} \\
\hat{V}_{lp}(s^2C^2 + sCQ - sCFx) &= \hat{V}_{in}(F^2b + FQa) - F^2\hat{V}_{lp} \\
\hat{V}_{lp}(s^2C^2 + sCQ - sCFx) + F^2\hat{V}_{lp} &= \hat{V}_{in}(F^2b + FQa) \\
\hat{V}_{lp}(s^2C^2 + sCQ - sCFx + F^2) &= \hat{V}_{in}(F^2b + FQa) \\
\frac{\hat{V}_{lp}}{\hat{V}_{in}} &= \frac{F^2b + FQa}{s^2C^2 + sCQ - sCFx + F^2} \\
&= \frac{F^2b + FQa}{s^2C^2 + sC(Q - Fx) + F^2} \\
&= \frac{b + a\frac{Q}{F}}{s^2\left(\frac{C}{F}\right)^2 + s\frac{C}{F}\frac{Q - xF}{F} + 1}
\end{aligned}
$$

$$
H(s) = \frac{b + a\frac{Q}{F}}{\frac{s^2}{\left(\frac{F}{C}\right)^2} + 2\frac{s}{\frac{F}{C}}\frac{\left(\frac{Q}{F} - x\right)}{2} + 1} \tag{15}
$$