# Application Note

CML Microcircuits

COMMUNICATION SEMICONDUCTORS

# Frequency Estimation for a VCO using a Negative Resistance Amplifier

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| Additional Resources | A spreadsheet that calculates the approximate VCO frequency and gives typical worked examples can be downloaded together with this Application Note. |

## 1 Introduction

Some of CML's RF products, including the CMX994, provide an integrated negative resistance amplifier that can be used with external components to create a VCO. Using this integrated amplifier reduces component count, cost and size relative to using an external VCO circuit.

This application note describes how to estimate the operating frequency of VCO designs that use the negative resistance amplifier, taking both discrete component values and some realistic stray capacitances into account.

## 2 History

| Version | Changes | Date |
|---|---|---|
| 1 | Initial Version | 04-10-13 |
| | | |

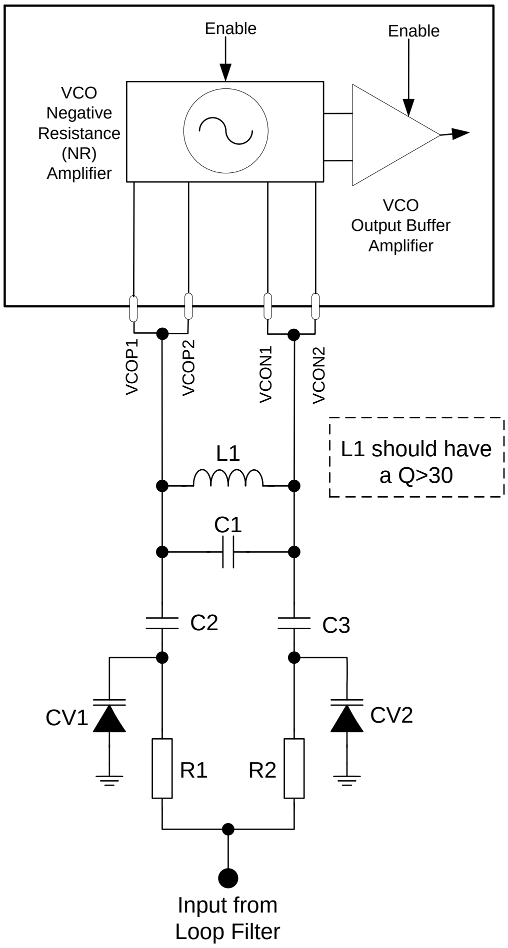


**Figure 1 Example External Components – VCO External Tank Circuit**

| | | | |
|---|---|---|---|
| L1 | 8.2 nH (Note 1) | CV1 | SMV1705-079LF |
| C1 | 8.2 pF (Note 2) | CV2 | SMV1705-079LF |
| C2 | 22pF | R1 | 10kΩ |
| C3 | 22pF | R2 | 10kΩ |

Note 1: Tolerance of 2% or better recommended
Note 2: Tolerance of 5% or better recommended

**Table 1 Internal VCO Amplifier Tank Circuit for 440MHz Operation**

Figure 1 presents a method of utilising the negative resistance amplifier to create a VCO. There are other ways to configure such a design but the principles are similar. Several factors influence the precise frequency obtained. For example, stray capacitance and inductance plus variation in the negative resistance value with frequency and amplitude. It is usual for some empirical work to be carried out to ensure that a design is nominally centred at the required frequency and has suitable tolerance to allow the required frequency range to be obtained. This note provides initial guidance to get reasonably close to the required operation. It is assumed that the basic concepts of a varactor-controlled VCO are understood, otherwise the theory is available from many text books.

Four pins are used in the design to reduce the effects of the package internal inductance that can otherwise restrict the maximum operating frequency. VCOP1 and VCOP2 are the positive pair, VCON1 and VCON2 are the negative pair. The tank inductor should be placed as close as possible to these package pins. Note: for recommendations on PCB layout see the device datasheet.

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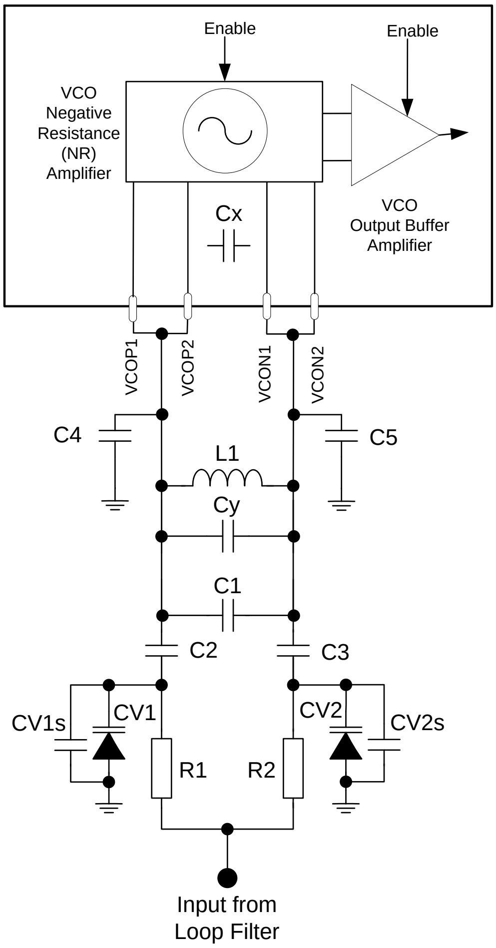


**Figure 2 VCO External Components (showing stray components)**

Figure 2 shows the VCO configuration with extra capacitors representing unavoidable strays. It is necessary to estimate these stray capacitor values to get close to the required centre operating frequency. Typical example values are given in Table 2. L1 may also add additional stray series inductance depending on the board layout. This should be added to L1’s value.

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| Ref Designator | Description | Nominal Value |
|---|---|---|
| Cx | Internal chip capacitance | 1.8pF |
| Cy | Parallel capacitance of L1 | 0.3pF |
| C4, C5 | Capacitance of circuit board tracks from CMX994 to L1 | 2pF |
| CV1, CV2 | Varactor capacitances | 13pF |
| CV1s, CV2s | Lumped stray circuit board capacitance on each varactor | 1pF |
| C2, C3 | Series coupling capacitances | 22pF |
| C1 | Main tank capacitor | 8.2pF |
| L1 | Main tank inductance | 8.2nH |

**Table 2 Nominal Discrete and Stray Component Values**

The resulting VCO nominal operating frequency (f) is given by:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Where L= L1 and C is given by:

$$C = C1 + Cx + Cy + \left(\frac{1}{CV1+CV1s} + \frac{1}{CV2+CV2s} + \frac{1}{C2} + \frac{1}{C3}\right)^{-1} + \left(\frac{1}{C4} + \frac{1}{C5}\right)^{-1}$$

Using the values of Table 2 yields an estimated nominal frequency (f) of 445MHz for Figure 2.

An Excel spreadsheet that helps with choosing component values can be downloaded together with this Application Note. It should be noted that the stray components can have a significant impact on the frequency obtained, especially at higher frequencies, and accurate estimation is not always easy to do. As a result, some experimentation may be required. Examples are given in the spreadsheet including some based on CML's evaluation boards. Note that in these boards there is an additional stray series inductance of about 0.5nH.

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