Section2:
VCO Gain Measurements.

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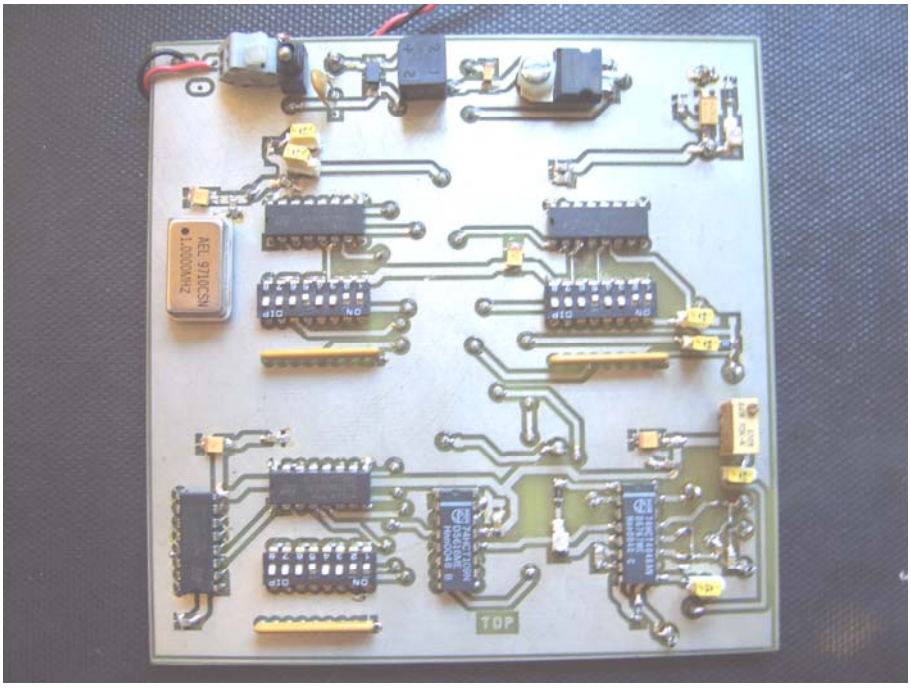
Document Priority: Normal:
Associated Documents: Appendix 1; Pll demoboard Schematic.
Test Equipment: 0-30V Lab PSU; Oscilloscope - Agilent 54622D, RS232 lead and software. VCO gain adjustment resistor, Trimmer tool.
Note: this document is for review purposes only. Some items have been deliberately removed

Purpose:

The material in this section relates to measurement and characterisation of the VCO (voltage controlled oscillator). Two methods of characterisation are explained. These relate to direct VCO gain measurements, and inferred measurements. In addition a simple check on VCO noise is performed.



Contents

Section Contents

Figures and Tables

Introduction:

Aims:

The primary aim of this section of the practical module is to ……
Familiarise the student with two typical methods of VCO gain measurement, and additionally provide a comparison of the methods.

Objectives:

After completing this practical module the student should be able to.

- ✓ Perform VCO gain measurements using both direct control and inferred methods.
- ✓ Investigate the VCO gain over different portions of the VCO transfer characteristic.
- ✓ Make simple measurements on VCO noise and observe the effect that the locked PLL has on VCO noise.

Module Overview:

The purpose of this module is to investigate VCO (Voltage controlled oscillator) gain measurement techniques.
A VCO produces an output signal with a frequency that is proportional to its input control voltage. For practical purposes many VCOs are designed to be as linear as possible over their operational range. In certain applications, such as, FM demodulation, and carrier recovery, this linearity is particularly important.

If an initial linear approximation is valid over the range of operation, the VCO gain transfer characteristic (often designated as K_0 or K_{VCO}) is defined as.

$$KVCO = \frac{F2 - F1}{V2 - V1} \qquad \text{(Hz/V) or (rps/v) if multiplied by } 2\pi$$

Equation 1 VCO gain equation.

Where: V1 would be an initial control voltage applied to the VCO input and F1 would be the corresponding frequency response.
V2 would be another larger control voltage applied to the VCO input and F2 would be the corresponding frequency response.

NOTE: For measurement purposes it is permitted to use the units of Hz/V or rps/v (Hertz per volt or radians per second per volt). However, when inserting the VCO gain value into the overall PLL transfer function it is traditional to use the rps/v form of the equation.

A graphical representation of the VCO output frequency change with respect to the VCO input control parameter is provided below.

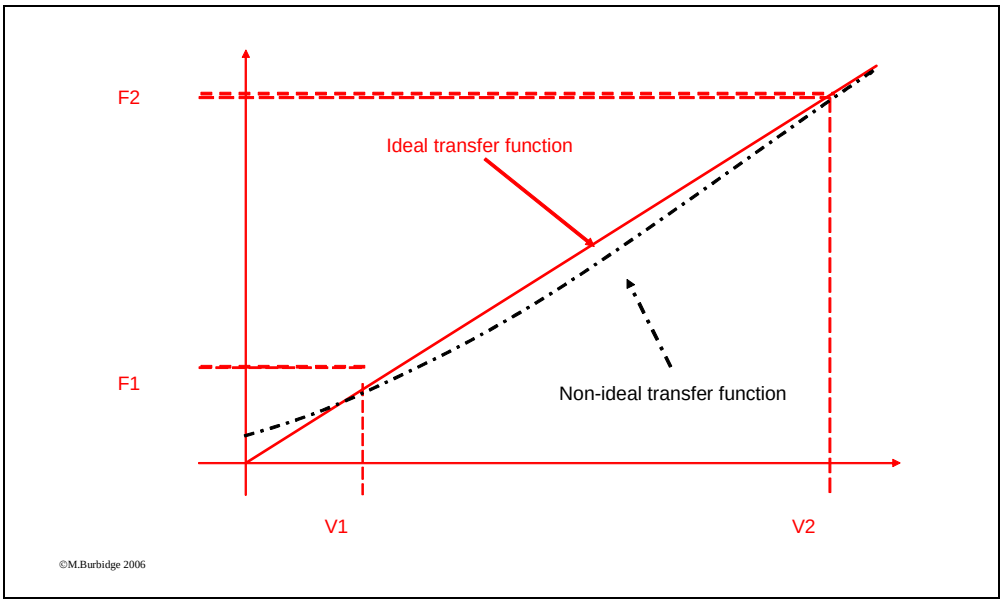


Figure 1Ideal and non-ideal transfer function curves for VCO gain.

The red line in figure 1 depicts the linear operation of a particular VCO for a corresponding input control voltage. In addition, the output frequency response for a VCO that is slightly non-linear is included (dashed line). It should be apparent, that detection of this non-linearity, would require further incremental VCO gain measurements between (V1, F1) and (V2, F2). In general the, choice of taking more measurements would depend upon the particular application.

This module describes two particular methods of VCO gain measurement that are briefly explained below:

1) **Direct measurement:** For direct measurement it is implied the PLL loop is open at the VCO input and that the control voltage is applied from an external source.
2) **Inferred measurement:** With inferred measurement the PLL loop is locked and the VCO control voltage and output frequency is measured for different divider settings. The measured values are used to determine the VCO gain.

Further details of these measurements will be given in later sections of this document.

In addition, to the VCO gain test, a coarse measurement of VCO output noise will be performed. This measurement will follow on from the direct VCO measurement.

Basic Board Set-up:

This section outlines the initial jumper and divider settings that have to be made before commencing the test.

Warning: Before commencing any of the tests ensure that:

- The initial board checks in section 1 have been carried out
- The information supplied in Appendix 1 has been read, and understood.

The diagram below shows the topside silk screen of the PLL test demonstrator board, the outlined numbered sections indicate areas of the circuit that are of importance in this practical session.

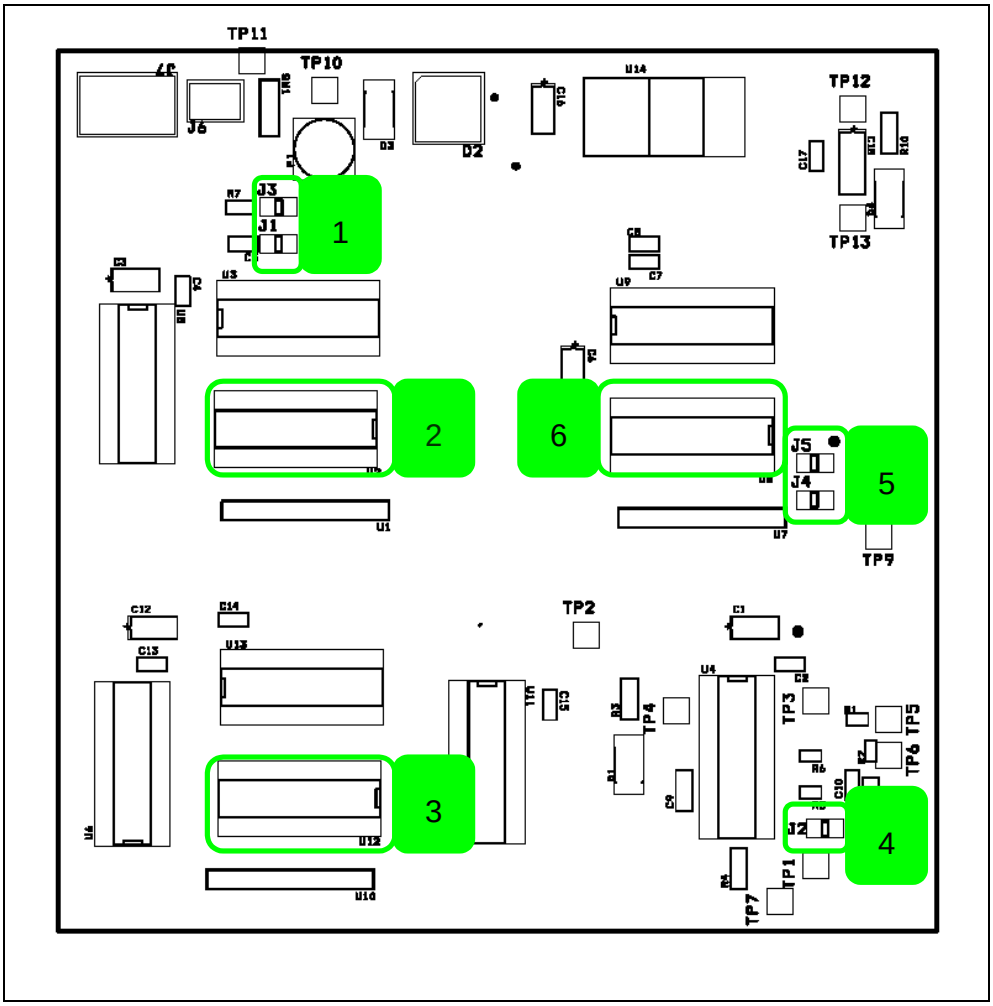


Figure 2Pll demonstrator board topside silkscreen.

With reference to figure 1 the table below explains initial set-up details for the particular test.

Jumper Block#	Associated components (Location)	Position details	Comments
1	J3 (Top) J1 (Bottom)	OFF ON	Isolates external reference.
2	U2 8way DIL Switch.	11101100 [1][2]	Divides the master oscillator by 20. Sets divided reference to 50KHz
3	U12 8way DIL Switch.	11101100 [1][2]	Divides master oscillator by 200 then by 20.
4	J2	OFF	Isolates the PLL loop filter from the VCO control input.
5	J4 (Bottom) J5 (Top)	OFF ON	Isolates the on board toggle signal from the PLL feedback divider
6	U8 8way DIL Switch.	11101100 [1][2]	Sets the PLL feedback divider ratio to 20.

Table 1 Initial Pll demonstrator board set-up.

Notes:
[1] 1 = Switch in the on position.
0 = Switch in the off position.
[2] This is set to give an initial overall PLL feedback divider ratio of 40 (remember that the VCO output signal passes through a high speed divide by two element before being fed into the lower speed adjustable feedback divider).

Test Hardware Physical set-up:

This section outlines the initial interconnection details for the external test equipment. The following figure illustrates the test pins that are used for this particular test.

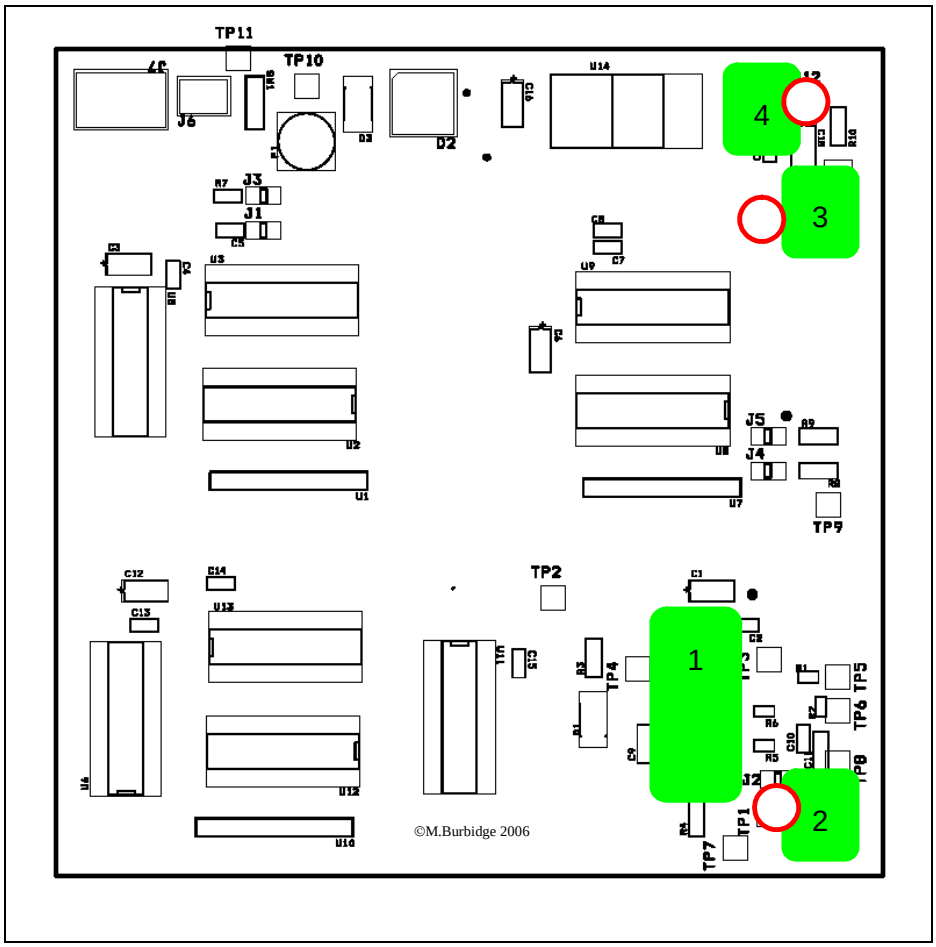


Figure 3Test pin and component details.

With reference to the above diagram the table below indicates the function of the test pins for this particular test.

Block#	Component / (Schematic Ref /PIN)	Test function
1	PLL (U4; pin 4)	Allows monitoring of the VCO output frequency.
2	Test pin (TP1)	Allows application of an external control voltage. (also allows monitoring of this voltage).
3	Test pin (TP13)	Board ground connection.
4	Test pin (TP12)	Board +5V connection.

Table 2 Test pin function table.

With reference to table 2 and figure 2 the initial oscilloscope connections should be made as follows.

Oscilloscope settings:
Connect the channel 1 probe tip to point 2 in figure 1.
Connect the channel 2 probe tip to Pin4 of the PLL.
Connect both of the earth clips to point 3 in figure 1.
The initial oscilloscope settings can be loaded from the file "QFILE_03" on floppy disk using the following buttons on the oscilloscope.
Save/Recall =>Recall =>From QFILE_03

Control voltage adjustment resistor settings:
For this experiment we need to be able to manually control the VCO control voltage. Manual control is facilitated by use of a multi turn potentiometer with attached flying leads. The leads should be connected as follows.

Lead colour	**PLL board connection point (see figure 2) (*schematic ref*)**
Red	4 (*TP12*)
Black	3 (*TP13*)
Green	2 (*TP1*)

Table 3 Control voltage resistor connection points.

After these connections have been made the board can be powered up.
If every thing is working correctly an oscilloscope display similar to the one shown below should appear.
Important note: Some board versions may have the variable resistor mounted on the board. If this is the case the resistor connection details given in table 3 can be ignored. See Appendix_1 section 3 for further details.

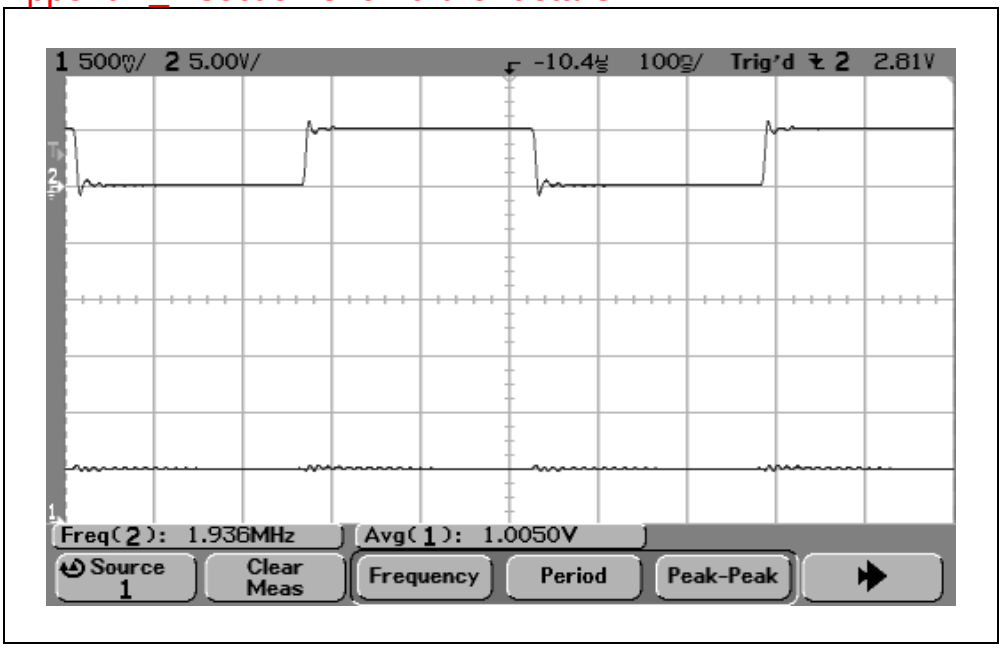


Figure 4Initial oscilloscope display for the VCO test

2.0 Direct VCO gain measurement.

In this section the VCO gain will be measured using direct methods.
Direct measurement of the VCO gain will involve incrementally setting the VCO control voltage to various values and measuring the corresponding VCO output frequency. The measured voltage and frequency values are entered into an EXCEL™ spreadsheet allowing the VCO transfer curve to be plotted.

2.1 Direct VCO measurement procedure.

Oscilloscope settings:
The oscilloscope settings should be the same as those mentioned in the previous section (see pg 8).
The measurement procedure details are listed below:

1) Before carrying out the measurements the XCEL spreadsheet 'VCOmeasurment.xls' should be opened.
2) The spreadsheet contains two sets of values consisting of….
    a. Blank entries of frequency measurements for VCO control voltages from 1 to 4.5 volts in 100mV increments [1].
    b. Blank entries of voltage and frequency measurements for loop divider settings of 20 to 30. This is for use in a later section.
3) As the appropriate values are entered, the spreadsheet will automatically plot the VCO transfer characteristic as the appropriate values are entered.
4) To take the measurements adjust the variable trimmer resistor until the scope indicates the required voltage, and then place the corresponding frequency measurement in the appropriate cell [1]. The values can be placed into the cells automatically using the Agilent 54600 scope toolbar as follows.
    a. When the required voltage value has been set place the spreadsheet cursor in the required cell.
    b. Locate the Agilent oscilloscope toolbar at the top of the spreadsheet and select the single measurement option.
    c. When the single measurement dialogue pops-up select the required measurement for the correct channel. If the scope was set up in accordance with the instructions in this document the following values should apply.
        i. *Scope channel [1-on]; Function [Volts Average]*.
        ii. *Scope channel [2-on]; Function [Frequency]*.

Be sure to place the measured values in the frequency and measured values column

Notes:
[1] Don't spend too much time trying to get the control voltage exact, an accuracy of ± 5mV will be sufficient for the exercises.

Questions:
The described method of VCO gain measurement was used to estimate the VCO gain to be used for the corresponding simulation models. From the graphs that were created from the experiment and using equation 1 estimate the VCO gain for the following control voltage differences.

1.0 to 4.5 volts
3.5 to 4.0 volts
2.0 to 2.5 volts

Note: that the VCO gain may vary slightly between devices.

1) Does the VCO gain vary significantly over different measurement ranges? and what value do you value of gain do think it would be better to use in a simulation model and why?

2.2 Simple VCO noise experiment.

Questions:

2) Did you observe any noticeable difference between the VCO output signal between the open loop and PLL closed loop conditions ?

2.3 Indirect VCO gain measurement.

Ensure that the PLLdemo board settings are the same as those outlined in table 4.
Before carrying out the measurements the XCEL spreadsheet 'VCOmeasurment.xls' should be opened.

Make the following oscilloscope settings:

Oscilloscope settings:
Connect the channel 1 probe tip to point 2 in figure 1.
Connect the channel 2 probe tip to Pin4 of the PLL.
Connect both of the earth clips to point 3 in figure 1.
The initial oscilloscope settings can be loaded from the file "QFILE_03" on floppy disk using the following buttons on the oscilloscope.
Save/Recall =>Recall =>From QFILE_03

When the equipment has been set-up set the feed back divider to divide by the values shown under the Indirect VCO gain measurement column in the spreadsheet. For each divider value enter the appropriate voltage and frequency value. Note that the method for doing this is provided in section 2.1 on page 9. After the measurement values have been entered a VCO transfer characteristic should be automatically plotted in the corresponding graph. In addition, the approximate VCO gain between the divider ratio of 20 and 30 should be automatically calculated.

Questions:
Compare the calculated end point VCO gains between the two explained methods. Also compare the VCO gain calculated for between a divider ratio of 25 and 30 with the VCO gain for the nearest corresponding voltages in the direct measurement graph.

3) Consider that the measured VCO gain will be used in a model that only need to generate a frequency step response plot for a step output of frequency between 2.5 and 2.6 MHz.
    a. What would the best method of VCO gain calculation be?
    b. What values from the graph would you use?

VCO gain measurement; Answer Sheet 2:

Student Name:……

Date:……..

This sheet relates to any "in text" questions that were asked in this practical.
If response plots or post processing graphs were requested, please name them and attach them to this sheet.

Answer#	
1	
2	
3	
4	
5	
6	
7	
8	
9	

Technicians set-up notes and tutors details:

For this practical the equipment should initially be set up as outlined in section 1. In addition to the oscilloscope and power supply, the following equipment and software is required.

Hardware:

- Variable resistor for VCO gain adjustment. (see table 3 page 8).
- RS232 lead to scope. (see section 2.1 page 9).

Software:

- Scope setting files => QFILE_03.* and QFILE_04.* in the local instruments files folder. These files should be copied onto a floppy disk and distributed to the students.
- VCO measurement "VCOmeasure.xls" in the local "EXCELFiles" folder.
- Agilent scope toolbar for EXCEL.

Answers and further information:

- Details of the switch settings required for the indirect gain measurements of section 3 are supplied in the AnswerSheets folder.
- An example VCO gain measurement spreadsheet is provided in the local AnswerSheets folder.
- Sample answers to the questions are provided in the local AnswerSheets folder.