

# **PLL Test Course:**

## **Section 3**

### **Phase Transfer Monitoring.**

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**Associated Documents:** Online course material, Lab session Appendix 1, Further documents are mentioned in this test and are also summarised in appendix 1

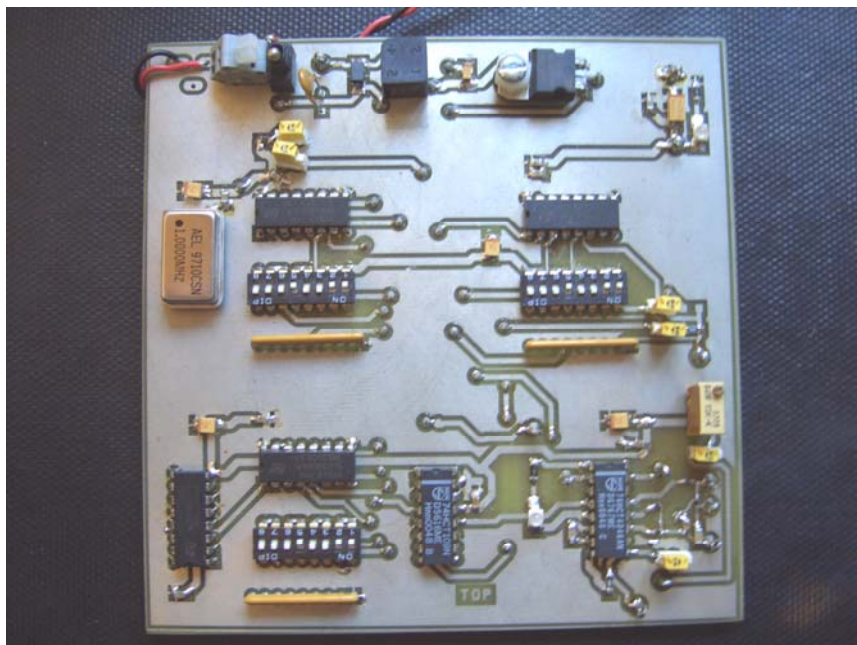
**Test Equipment:** 0-30V bench PSU, Signal Generator-HP33120A, Oscilloscope-Agilent54622D + probes + RS232 cable. Windows PC.

**Software:** Oscilloscope PC connection software, EXCEL.

Note: this document is for review purposes only. Some items have been deliberately removed

**Purpose:**

The material in this section explains the procedures involved in making Phase transfer measurements for CP-PLLs.



## **Contents**

### **Section Contents**

Aims:.....	3
Objectives: .....	3
Module Overview and Specific Details: .....	3
2.0 Basic Board Set-up: .....	7
3.0 Test Hardware Physical set-up: .....	9
4.0 Test Hardware Initial Instrument Settings and notes: .....	11
Oscilloscope settings:.....	11
Signal Generator Settings: .....	11
5.0 Initial Stimulus Adjustment and Response Analyses: .....	13
Measurement Control Details: .....	
Response Analyses: .....	
Questions and course work: .....	13
6.0 Further Experiments: .....	14
Questions: .....	14
PLL Phase Transfer function measurement Answer Sheet 3: .....	15
Technicians Laboratory set-up notes: .....	16

### **Figures, Tables and Equations**

Figure 1	Experimental measurement of phase. ....	4
Figure 2	PLL demonstrator board topside silkscreen. ....	7
Figure 3	Test pin details .....	9
Figure 4	Test Hardware Physical setup. ....	10
Figure 6	Signal Generator Controls (see associated text). ....	17
Table 1	Jumper and switch connection details.....	8
Table 2	Test pin function table. ....	10
Table 3	Cable connection details. ....	16
Equation 1	Conventional dB Magnitude calculation .....	4
Equation 2	Experimental formulae for calculating phase. ....	5
Equation 3	Modified PLL specific magnitude calculation.	

## Introduction:

### ***Aims:***

The primary aim of this section of the practical module is to allow the student to make practical experiments related to transfer function measuring of Charge-Pump phase locked loops. It is hoped that the exercises undertaken in this lab session will substantiate theoretical material and simulation work studied in the online material.

### ***Objectives:***

After completing this practical module and studying the associated online material the student should be able to.

- ✓ Understand the subtle differences between conventional transfer function monitoring and transfer function monitoring of Phase locked loops.
- ✓ Understand the set-up of appropriate input signals (on various equipment) to enable transfer function measurements of CP-PLLs to be carried out.
- ✓ Collect oscilloscope data from the PLL.
- ✓ Posts process the information to obtain graphical magnitude and phase information for the transfer function, and also be able to analyse the plots and compare them with theoretical results.

### ***Module Overview and Specific Details:***

In this module the transfer function of a Charge-Pump phase locked loop will be measured. The results of the measurements will be used to extract phase and magnitude response plots for the PLL. The transfer function of a PLL (or any real system) is important because it uniquely defines the operation of the system. In consequence transfer function measurements and parameters are often used for the design and characterisation of physically realisable systems. In many instances systems are designed to approximate a second order behaviour, this is partly due to the fact that a vast amount of information exists for modelling systems of this order. In fact, many control theory texts cover second order system response in great detail.

It must be noted that for the following discussions it is assumed that the reader is familiar with techniques used for transfer function measurements of commonly encountered electrical or mechanical systems, such as RLC networks, mass spring damper systems, OP-amp filters etc. However, for completeness the following details of transfer function measurements relating to a typical electrical system are now explained. Considering a series connected RLC circuit the key features apply:

- The input signal can be a time varying voltage signal  $\Rightarrow V(\text{in})$ .
- The output signal can be measured in terms of voltage  $\Rightarrow V(\text{out})$
- To experimentally measure the transfer function of the system we would:
  1. Apply a sinusoidally varying input voltage to the system. Ensuring that the input voltage sinusoid does not drive any part of the measurement system into non-linearity at any frequency of interest.

2. Keep the amplitude of the input sinusoid constant and increase the frequency whilst monitoring the sinusoidal output response of the circuit under test. Note that the measurements are taken over the frequency of interest, and the frequency range used will generally be dependant upon the particular application.
3. We may also want to measure the phase response of the system and this can be accomplished by measuring the time difference between the peaks of the input and output waveforms at a particular excitation frequency.

Note that in step 2 the designer or test engineer will usually have prior knowledge of how the system should respond before any measurements are taken. In consequence measurements are commonly only taken around the poles (or breakpoints) of the system. Multitone testing {5} can be regarded as an automated application of this type of manual measurement process.

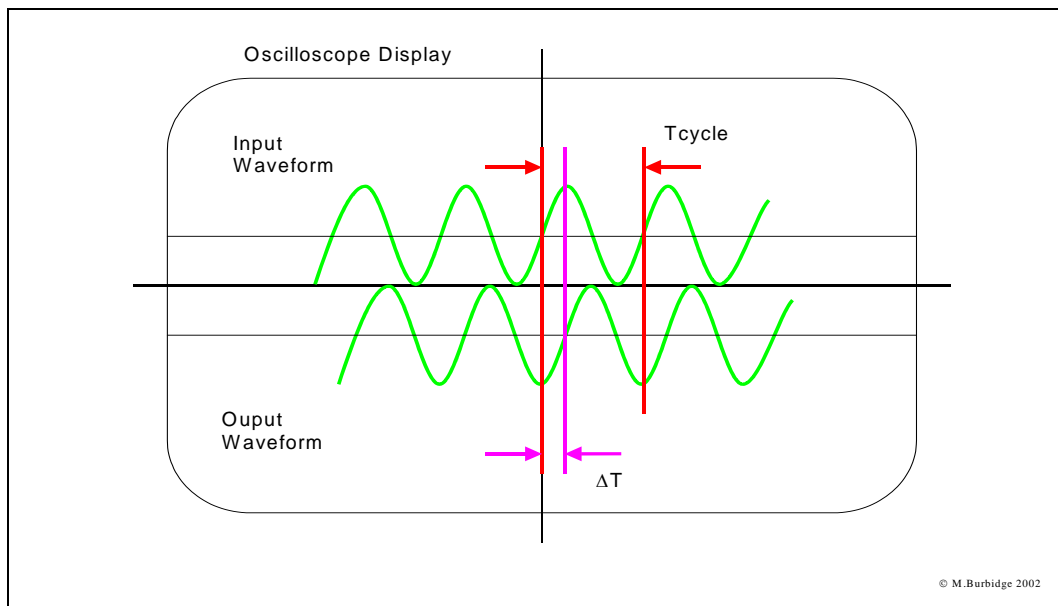
From the measurement results of the above technique the magnitude and phase information can be extracted as follows:

The magnitude information in dB is found by:

$$\text{Magnitude} = |H(j\omega)|_{dB} = 20 \log_{10} \left( \frac{V_{out}}{V_{in}} \right) \quad (\text{db})$$

#### Equation 1 Conventional dB Magnitude calculation

And the phase information can be found experimentally by comparing the phase difference between the input and the output waveform. This is best explained graphically.



**Figure 1** Experimental measurement of phase.

In the above diagram:

Tcycle represents the time measured for one complete cycle of the input waveform.

ΔT represents the measured time difference between the input and output waveform.

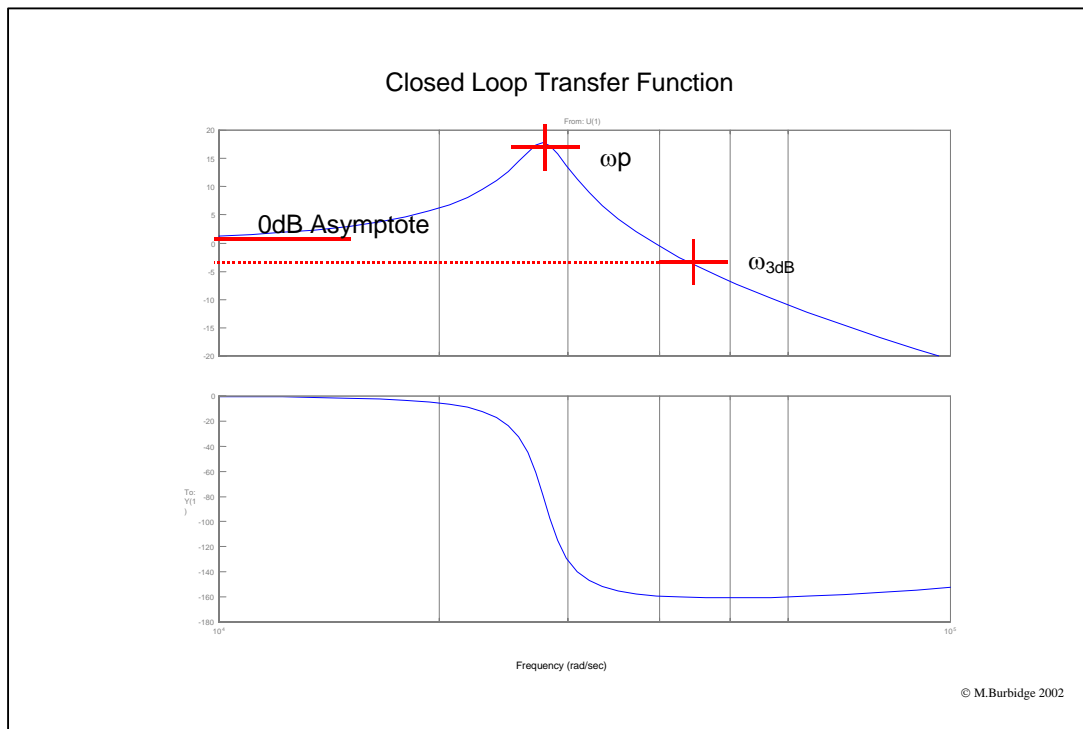
Using Tcycle and ΔT the phase difference (Δφ) between the input and output signal can be estimated using the following relationship.

$$\phi(j\omega) = \Delta\phi = \frac{\Delta T}{T_{cycle}} \cdot 360 \quad (\text{Degrees})$$

**Equation 2 Experimental formulae for calculating phase.**

The preceding techniques would be used to experimentally characterise a conventional system. However for a PLL system it must be remembered that the input and output parameters are in terms of time varying phase and not time varying voltages, currents etc. So to carry out a transfer function measurement of a PLL a sinusoidally varying phase (or phase modulation) has to be applied as the input parameter, and the output response will be a sinusoidally varying phase. To simplify the generation of a real input signal it can be shown that a phase-modulated signal is equivalent to a controlled frequency modulated signal. This is a simplification because it is generally easier to generate FM using commonly available signal generators. Thus throughout the lab session we will attempt to carry out transfer function tests using frequency modulated input signals. Note that the comparison of FM and PM and a derivation applicable to this experiment is provided in {1}.

For completeness the expected response of a typical second order system is given below, along with a brief explanation of how the parameters relate to PLL operation.



**Figure 1 Typical magnitude and phase plots for a second order system.**



## 2.0 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.

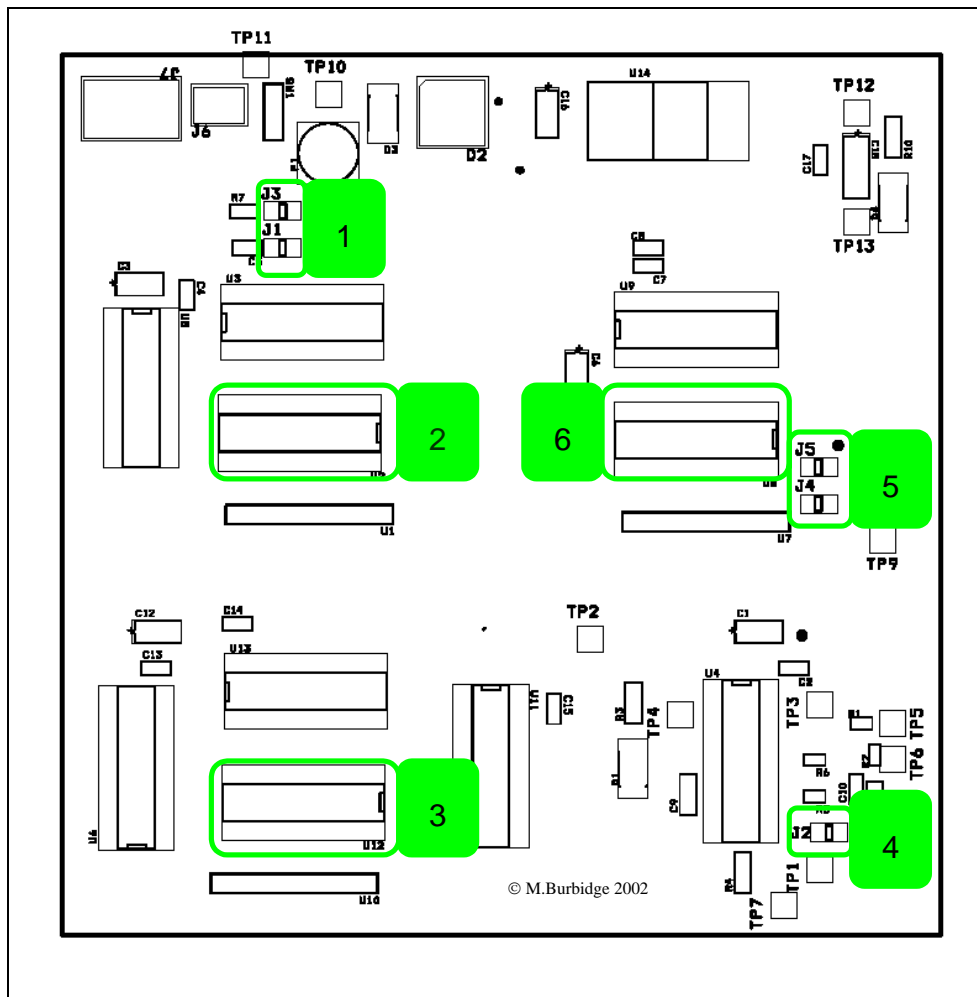


Figure 2PLL demonstrator board topside silkscreen.

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

Block#	Associated components (Location)	Position details
1	J3 (Top) J1 (Bottom)	ON OFF
2	U2 8way DIL Switch.	Don't care But preferably 1 1 1 1 1 1 1 1 [1] [2]
3	U12 8way DIL Switch.	Don't care But preferably 1 1 1 1 1 1 1 1 [1] [2]
4	J2	ON
5	J4 (Bottom) J5 (Top)	OFF ON
6	U8 8way DIL Switch.	Denary value of 19 Binary value 1 1 1 0 1 1 0 0 [1] [3]

**Table 1 Jumper and switch connection details.**

Notes:

[1] 1 = Switch in the on position.

0 = Switch in the off position.

[2] If all the inputs switches are set to on, the divider control inputs are pulled to ground, this means that the inputs are all zero and the output of the divider is always zero. For this experiment the connections are made to minimise switching activity from any unused circuitry.

[3] This is set to give an initial 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.

**Measurements to be made before proceeding:**

For the settings shown in table 1 the following points should be verified before proceeding. Many of the checks can be made using the oscilloscope.

- 1] U4, Pin 4 The output of the PLLs VCO should be at approximately 1.6MHz. This is because the PLL has no input signal at present, and in consequence the loop filter voltage will not increase, this means that the VCO will be operating at its lowest possible frequency.
- 2] U11, Pin 9 This pin should have a signal at half the frequency of the PLL signal.
- 3] U3, Pin 14 The output of the reference pre-scaler should be constant at 0.
- 4] U13, Pin14 The output of the toggle signal generator should be constant at 0.



### 3.0 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. The jumper and switch settings are initially left in the same positions as described in the previous section.

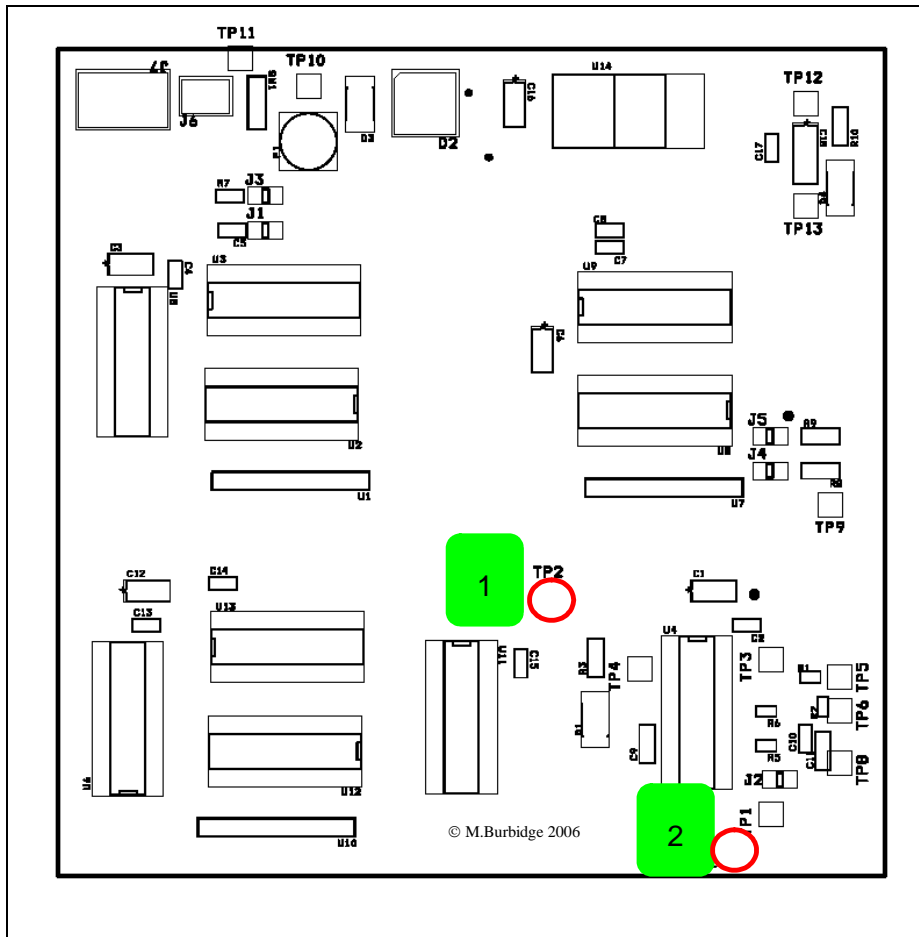


Figure 3 Test pin details

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

Block#	Test Function	Schematic Designator
1	Allows an external reference signal from the signal generator to be applied to the PLL.	TP2
2	DEMODO output of PLL. Allows monitoring of the PLL loop filter node, without unduly loading the node.	TP7

**Table 2 Test pin function table.**

The diagram below provides a schematic representation of the test hardware set-up.

**Figure 4Test Hardware Physical setup.**

Note that table 3 (in the technicians laboratory set-up note section pg 16) provides details of the cabling.

Before preceding you should ensure the physical connections are as shown and that they correspond to the details provided in table 3.

**\*Note the equipment should not be powered up at this stage.**

Now you should carry on to the next section.

#### **4.0 Test Hardware Initial Instrument Settings and notes:**

Before you start this section power up the equipment in the following order.

- 1) Power up the PLLTEST board.
- 2) Power up the signal generator.
- 3) Power up the oscilloscope.

Note that at this stage the oscilloscope will probably display meaningless data. The correct set-up details are given below.

##### **Oscilloscope settings:**

The initial oscilloscope settings can be loaded from the file "PH1TR1" on floppy disk using the following buttons on the oscilloscope.

*Save/Recall => Recall => From PH1TR1*

##### **Signal Generator Settings:**

The initial signal generator settings are stored on the machine in memory location 1. To load the settings use the following buttons on the signal generator.

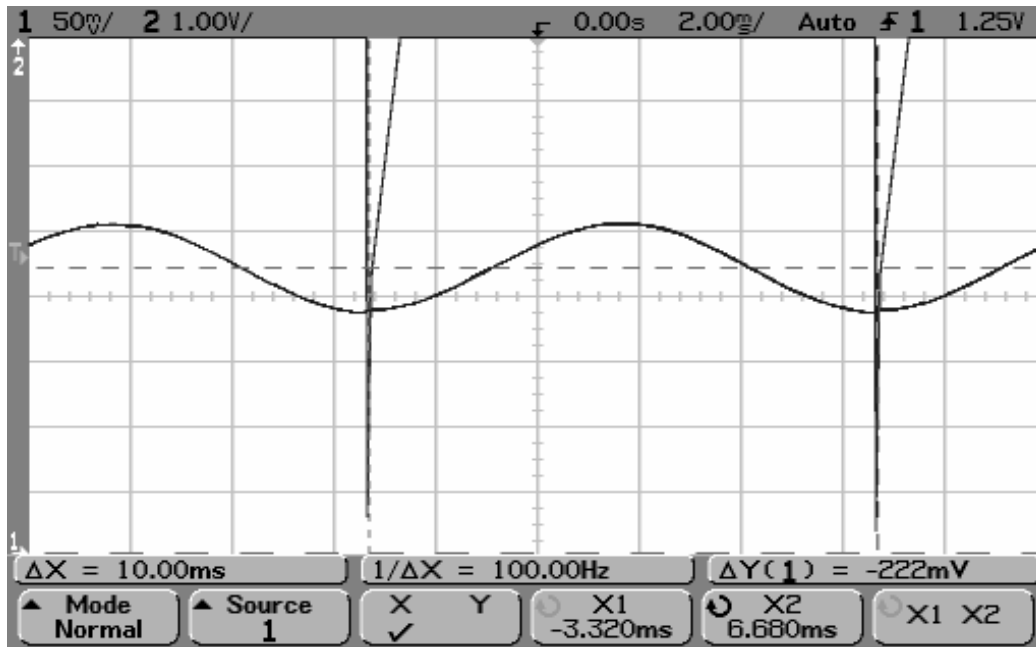
*Recall => Use the up and down arrow keys to select RECALL1 => Enter*

This will set up the signal generator with the following parameters.

- **Frequency modulated square wave.**
- **Centre frequency 50KHz.**
- **Maximum modulation deviation of 500Hz.**
- **Modulation frequency of 100Hz.**
- **Amplitude of 5 Volts (into a 50 ohm load)**

So the output signal from the signal generator will be a 0 to 5 volt square wave with a nominal frequency of 50KHz. This frequency will deviate in a sinusoidal fashion between  $\pm 500\text{Hz}$  at a rate of 100Hz.

When the signal has been loaded a sinusoidal signal should appear on the oscilloscope display for channel1. In addition a reference pulse should appear on channel2. This is shown in the following diagram.



**Figure 5 Output of initial oscilloscope plot**

The reference pulse (sharp pulse) indicates the start of each modulation cycle from the signal generator and is used to carry out phase response tests.

Before proceeding you should measure the time between the synch pulses (Hint, use the cursors) and confirm it is same as the modulation frequency mentioned in the settings above.

## **5.0 Initial Stimulus Adjustment and Response Analyses:**

### **Questions and course work:**

After plotting the phase and magnitude graphs they should be printed out with indications of where the appropriate PLL parameters can be determined. The graphs should be handed in. If possible compare the results with simulated results.

- 1) What is the measured natural frequency of the PLL?
- 2) What is the db magnitude of the peak.
- 3) Determine  $\omega_{3dB}$ .
- 4) Increase the modulation deviation to 5KHz using the signal generator controls. *Shift => level => and the appropriate control keys.* Now set the modulation frequency to the peak or natural frequency that was estimated from the graphs. What observations can you make about the output waveforms.
- 5) How can you increase the accuracy of the output response graphs?

## **6.0 Further Experiments:**

In the previous section you carried out a phase transfer measurement on a charge pump PLL using an overall feedback divider ratio of 40. Modify the PLL feedback divider ratio so that the overall division factor is 60 and carry out the same experiments as in section 5.

### **Questions:**

- 6) How do the PLL parameters change from the previous set of measurements?
- 7) What component values could you change to modify the PLL characteristics to that observed in the previous experiments?

### ***PLL Phase Transfer function measurement Answer Sheet 3:***

**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 Laboratory set-up notes:

The following information lists details for the laboratory set-up. Further information can be found in this set of lab notes. Figure 4 in this document gives the appropriate interconnect details for this particular lab. The equipment should be connected according to these notes prior to commencement of the lab session.

**Cable details:** Refer also to figure 4 in this document (PLL test course; Section 3; Phase transfer monitoring; Filename: PhaseTransfer.doc)

The cable details are shown below:

Cable connections	From	To	Cable type Details
Signal generator cable	Signal generator 50ohm output.	TP2 and GND on demonstrator board.	50 ohm BNC coax to miniature crocodile connectors.
Synch Cable	Signal generator Synch output.	Channel 2 scope.	50 ohm BNC to BNC coax.
Scope probe	TP7 and GND on demonstrator board.	To Channel 1 scope.	Normal oscilloscope probe.
Power leads	7 to 20V power supply.	To power connector on demonstrator board. Demonstrator board.	Twisted pair 2mm cable.

Table 3 Cable connection details.

### Equipment details and set-up:

#### Power Supply:

Variable 0 to 30V power supply capable of supplying 500mA current. The supply voltage output should be set between 7-20V.

#### Oscilloscope:

Agilent 54622D Mixed Signal Oscilloscope.

The set-up files are stored in electronic form as PH1TR1.SCP and PH1TR1.SCP in the instrument files folder relating to this module. These files should be copied to a floppy disk and distributed to the students during the lab session. The method for loading files is described on page 11 of this manual.

#### Signal Generator:

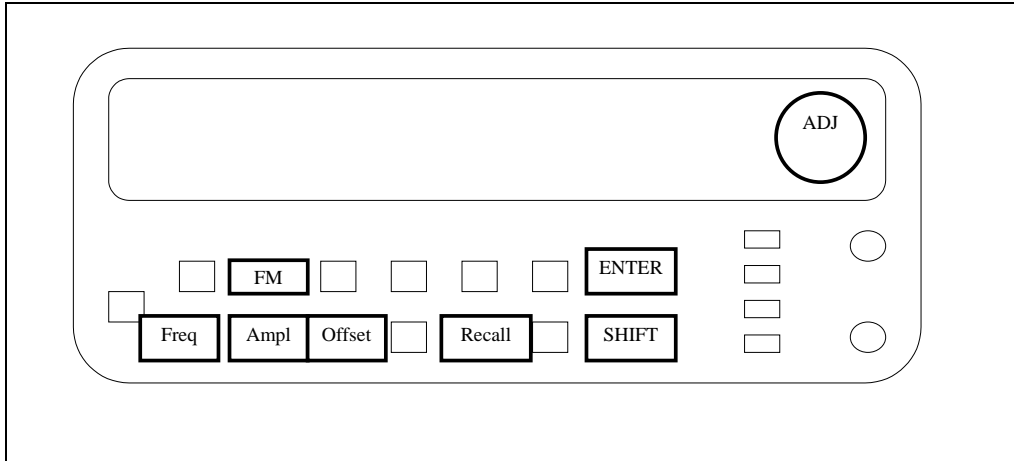
Hewlett Packard, 33120A 15MHz function arbitrary waveform generator:

To allow the students to recall the waveform, each of the signal generators used should have the appropriate waveform setting stored in memory location 1 (see page



11 of this document also). Note that if a different signal generator is used it will have to be set up appropriately in accordance with the signal description given on page 11.

To manually set-up the signal generator with reference to the associated diagram proceed as follows.



**Figure 6**Signal Generator Controls (see associated text).

Shift => FM => Freq.

Use the Adj control to adjust the frequency to 50KHz.

Shift => Ampl.

Use the Adj control to adjust the deviation to 500Hz.

Shift=>Freq.

Use the Adj control to adjust the modulation frequency to 100Hz. Note that this is the initial modulation frequency for the particular experiment.

Ampl.

Use the Adj control to adjust the signal amplitude to 5VPP.

Offset.

Use the Adj control to adjust the signal offset to 2.5VDC.

Shift=>Recall.

Use the up and down cursor keys and the enter key to store the waveform set-up in location 1.

Note: To adjust the modulation frequency for the transfer function test you use

Shift=>Freq.

And then select the desired modulation frequency with the Adj control.

### ***EXCEL spreadsheet files:***

The Excel files should be distributed to the students at the beginning of the lab session.

The excel files are set up so that the students can directly enter there measurement data into the spreadsheet. The associated magnitude and phase responses will be displayed automatically.

A blank spreadsheet file (PLLPhaseTransferTemplate.xls) exists in the ExcelFiles folder relating to this module. **This is the file that should be distributed to the students.**

Another Excel file (PLLPhaseTransferWorksheetMyEX.xls) also resides in a subfolder of this folder (WorkedExam) and contains a full example of the outputs taken from experimental measurements. **Do not distribute this file to the students**