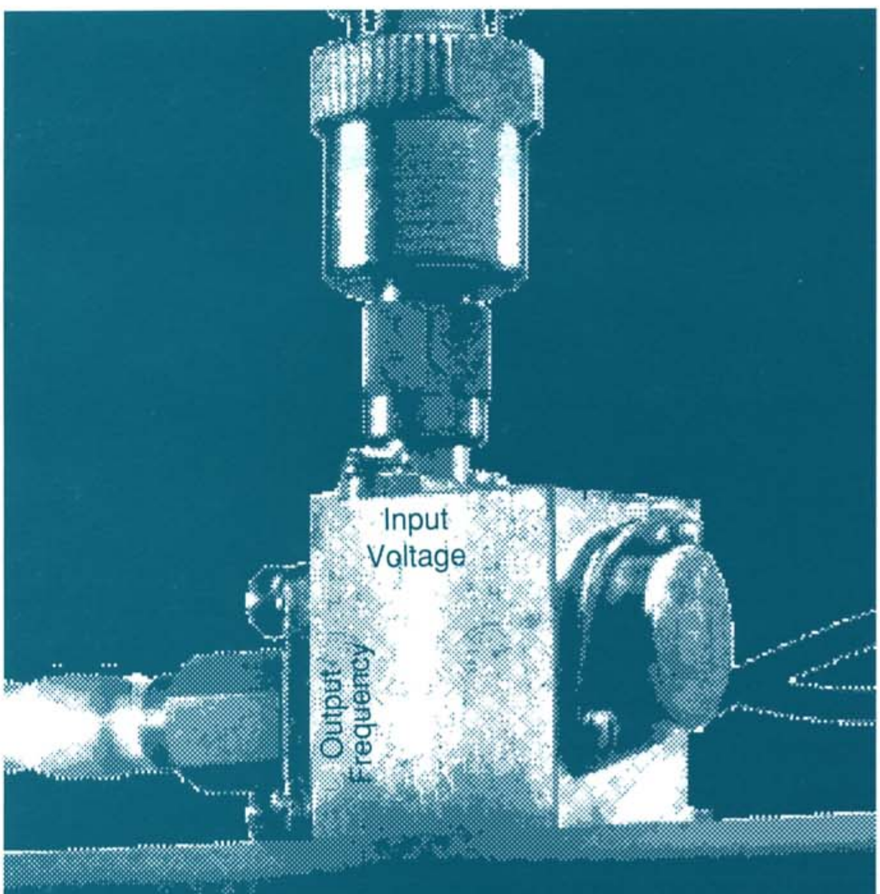
Application Note 377-2
Automatic Characterization Of Microwave VCO's

Using the HP 5361A 20 GHz Pulse/CW Microwave Counter



Profiling Your VCO in a Single VCO Voltage Cycle

If you want to characterize your VCO's step response with a single voltage step, the HP 5361A may not be the instrument of choice for you. Instead, choose one of HP's Frequency and Time Interval Analyzers such as the HP 5371A. These instruments are capable of measuring signal parameters on a single signal pulse, thus eliminating the need to repetitively cycle your VCO in order to characterize it. In addition, they offer the capability of profiling a repetitive signal in steps smaller than 20 ns.

The HP 5371A, along with the HP 5364A Microwave Mixer/Detector, provides powerful measurement capabilities, comprehensive phase and timing analysis, and built-in graphics. Contact your local HP representative or see Product Note 5371A-1 for more details.

Introduction

■ The HP 5361A 20 GHz Pulse/CW Microwave Counter is a useful tool for fully characterizing frequency and timing parameters of voltage controlled oscillators (VCO's) operating in the 500 MHz to 20 GHz frequency range. With little effort, the counter can not only quantify the relationship between the VCO's input voltage and output frequency, but can also provide precise data on the VCO's frequency response to a step in the input voltage.

The HP 5361A can be used independently or teamed with a high performance computer such as the HP 9000 Series 200/300. This Application Note describes the use of the HP 5361A and the HP Series 200/300 Computer, in conjunction with an HP 8112A (programmable) Pulse Generator and a digital oscilloscope, to obtain the frequency and timing characteristics of your VCO. The method described in this Note utilizes instrument control via the HP Interface Bus (HP-IB), thus yielding completely automatic, reliable, repeatable, and precise data collection.

Included in this Note is a description of the VCO characterization technique, and a step-by-step guide to setting up the corresponding automated characterization process.

An abbreviated version of the listing of the HP BASIC program which controls the test via the HP Series 200/300 Computer appears at the end of this Note to facilitate system integration and reduce the complicated measurement series to an automated, user-friendly program. The complete program, including simple graphics, can be ordered at no cost with the enclosed card.

The HP 5361A: a Useful Tool for Performing VCO Characterization

■ The HP 5361A is the first fully automatic pulse microwave counter to offer high-performance CW measurements. Its unique capabilities enable highly accurate characterization of VCO parameters, allowing measurement of:

- tuning linearity
- modulation sensitivity
- step response
- short- and long-term post tuning drift

Characteristics of a Voltage Controlled Oscillator

■ The primary characteristics of a VCO can be roughly divided into two categories: static (tuning linearity, modulation sensitivity, output frequency range); and dynamic (rise time, overshoot, post-tuning drift). These parameters are described below, and can all be easily measured by the HP 5361A.

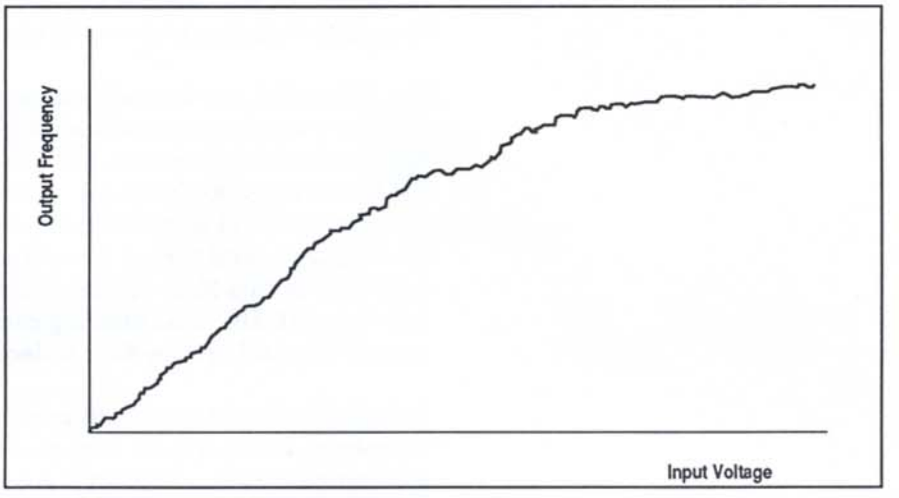


FIGURE 1. Typical VCO Tuning Linearity

In Figure 1, the tuning linearity (output frequency vs. applied voltage) of a typical VCO is shown. Figure 2 takes this one step further by examining the instantaneous derivative of this frequency vs. voltage relationship. Alternately referred to as the VCO's modulation sensitivity or differential nonlinearity, this parameter indicates the smoothness, or linearity, of the VCO's frequency vs. voltage response.

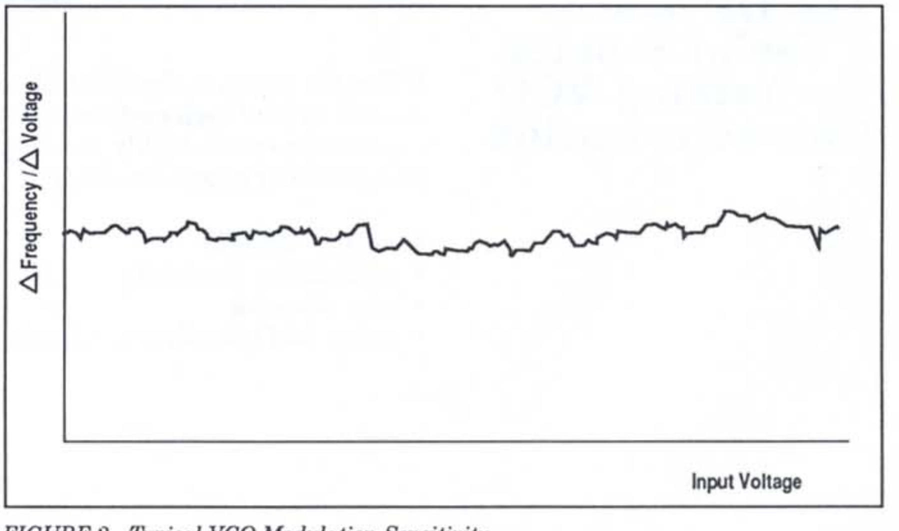


FIGURE 2. Typical VCO Modulation Sensitivity

Dynamic VCO measurements center around quantifying the change in the VCO's output frequency due to an abrupt change in the applied voltage (Figure 3). Some of the parameters of interest here are:

- time required for the VCO to change from f_0 to f_1 (rise time)
- linearity of this frequency change
- frequency overshoot and settling time

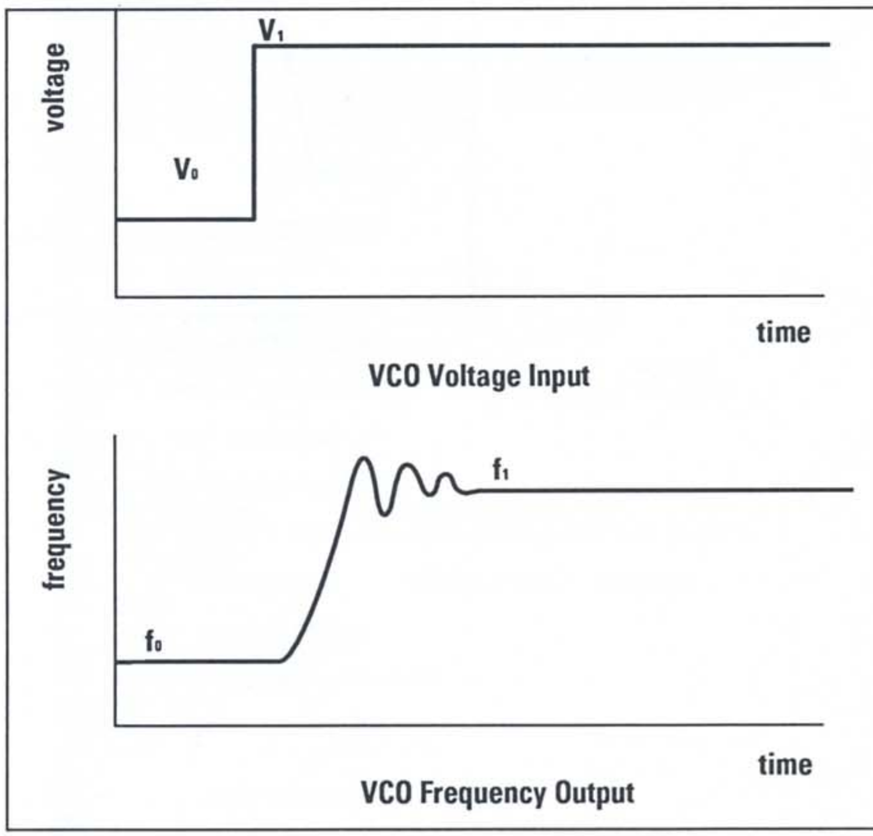


FIGURE 3. Typical VCO Response to Step Input

One final parameter which may prove very valuable to quantify is the VCO's Post Tuning Drift (PTD). As shown in Figure 4, this is the amount by which the frequency changes over a specified period of time, after a constant input voltage is applied. An ideal VCO would output a frequency which is time-invariant, and therefore ONLY dependent upon the input voltage. It thus would show no PTD.

The cause of this PTD is often thermal. A VCO's output frequency depends upon the values of its reactive components; as these components typically exhibit non-zero temperature coefficients, the resultant output frequency will change as these parts dissipate power and become warmer.

Post-Tuning Drift can be arbitrarily divided into two components: short-term (typically defined as the drift in output frequency over a 10 µsec to 1 sec time period); and long-term (the drift over 1 sec to 1 hr. or longer of operation). Depending upon your particular application and concerns, either or both of these drift measurements may be of importance.

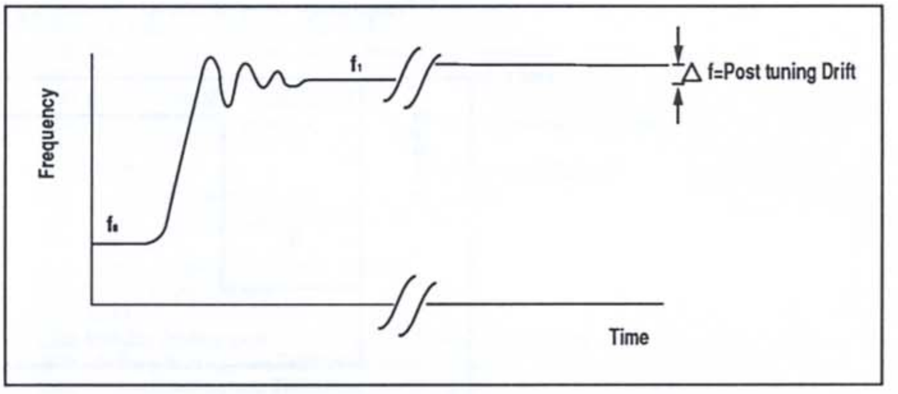


Figure 4. Typical VCO Post-Tuning Drift

External Gating Operation

■ Measurement of the VCO's static parameters is straightforward. A dc voltage is input to the VCO and the output frequency is measured by the counter. The input voltage is then incrementally increased, the new frequency measured, and the process repeated until the maximum input voltage is reached.

In order to measure the dynamic parameters (step response) of a VCO, an abrupt step in voltage is applied as an input. The resulting frequency change is then characterized using the external gating capability of the HP 5361A.

A time synthesizer, synchronized with the VCO's input voltage, produces a measurement gate of selectable width and delay. When used as the external gate of the counter, it can be made to step through the signal to obtain the frequency within each gate (see Figure 5). The summation of this data provides an accurate frequency profile of the incoming signal (in this case, the VCO's step response).

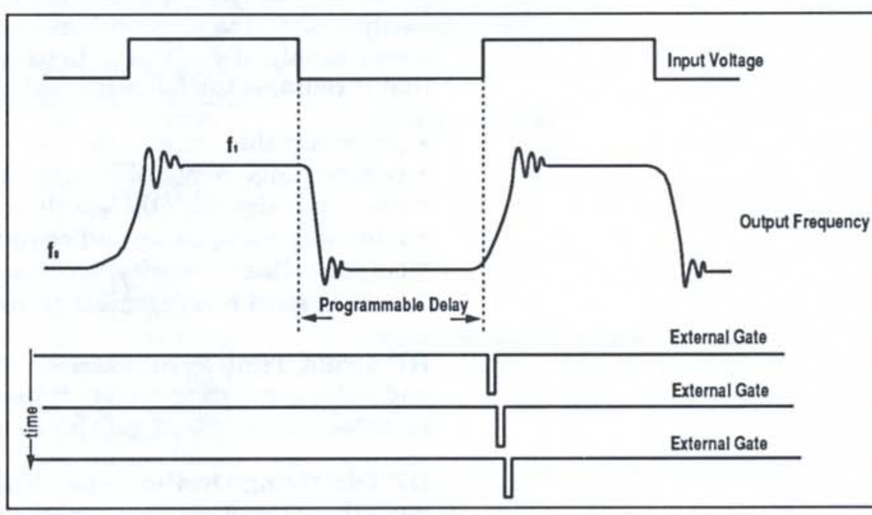


FIGURE 5. Profiling a Step Response Using an External Gate

Required Equipment

■ The automatic measurement system for performing VCO characterization, as shown in Figure 6 (next page), includes the following instruments:

HP 5361A 20 GHz Pulse/CW Microwave Counter.

HP 9000 Series 200 or 300 Technical Computer (or an IBM® PC/AT ™ - Compatible Computer and HP 82300 HP BASIC Language Processor). This high-performance workstation acts as the instrument controller for automatic VCO characterization. (NOTE: This computer facilitates the VCO characterization measurements described in this Applications Note, but is not required; manual profiling can be accomplished by systematically increasing the external gate delay and noting the measured frequency at each delay.)

HP 8112A Pulse Generator. This programmable pulse generator is used as the voltage source input for the VCO. The programming portion of this Note applies specifically to the HP 8112A, but can be easily modified to work with any programmable pulse generator or power supply. If you choose to use an alternative source, be sure that it contains the following features:

- programmable
- voltage range compatible with VCO specifications
- rise times significantly less than step response time of VCO
- minimum voltage step sufficient to fully characterize VCO
- output voltage linearity, accuracy, and drift sufficient to yield desired measurement accuracy

HP 5359A Time Synthesizer.* This highly accurate frequency and pulse generating system is used to produce the time-delayed external measurement gate for the counter.

HP Digitizing Oscilloscope. This oscilloscope is used to determine the internal delay inherent in your particular equipment.

In addition, three HP-IB cables, one microwave cable appropriate to the frequency of your signal, three cables for the gating function, and one cable for the power supply are required.

**While this Application Note is written specifically for a test setup using the HP 5359A Time Synthesizer to generate the measurement gate, any delaying pulse generator can be used. With minor modification to the attached BASIC program, any of the following generators can be substituted for the HP 5359A: HP 8112A, HP 8115A, HP 8131A, HP 8160A, and HP 8161A.*

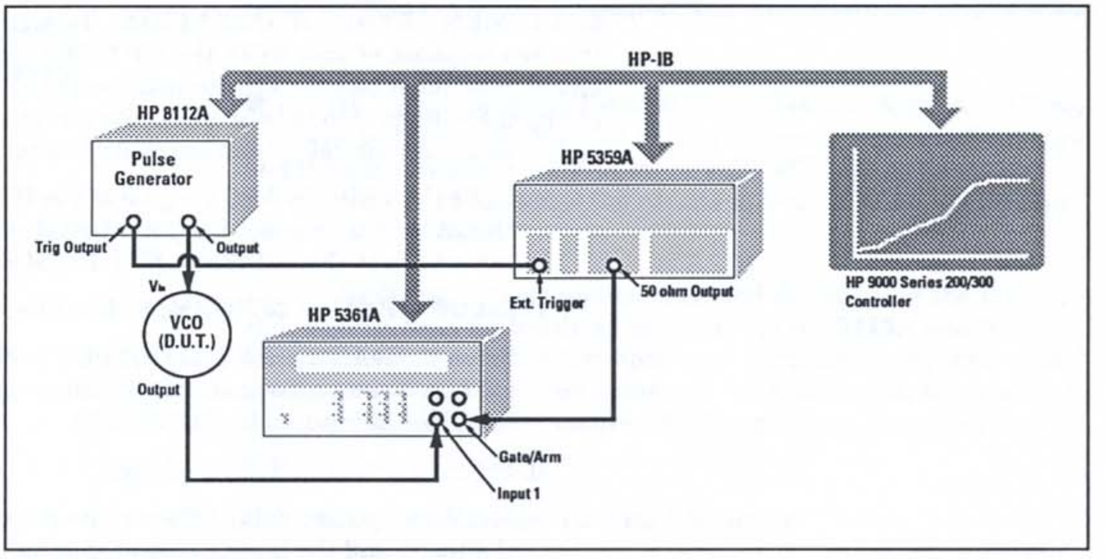


FIGURE 6. Measurement Set-Up Block Diagram

Measurement Setup

■ Connect the test equipment as shown in Figure 6. The following is a step-by step guide to connecting and running the system to perform VCO characterization.

1. **INPUT FREQUENCY**: While the HP 5361A counter provides two input ports for measuring various frequencies, only Input 1 is utilized for pulsed signals. Connect the VCO output to Input 1.
2. **EXTERNAL GATE SYNC -- TIME SYNTHESIZER**: Connect the TRIG OUTPUT of the HP 8112A to the HP 5359A EXT TRIGGER (used in the step response measurement section of the program).
3. **EXTERNAL GATE POLARITY**: Set the polarity of the HP 5359A 50 OHM OUTPUT to COMP POS, and the HP 5359A EXT TRIGGER slope to positive.
4. **EXTERNAL GATE**: Connect the 50 OHM OUTPUT of the HP 5359A (providing the delayed gate for the step response measurements) to the GATE/ARM IN of the HP 5361A.
5. **VOLTAGE SOURCE**: Connect the output of the HP 8112A Pulse Generator to the control voltage input of your VCO.
6. **HP-IB**: Connect the HP-IB between the Series 200/300 computer and the HP 5361A counter, HP 5359A Time Synthesizer, and HP 8112 Pulse Generator. Set the HP-IB addresses as follows:

Instrument	Address
HP 5361A	14
HP 5359A	9
HP 8112A	11

7. **EQUIPMENT SYNCHRONIZATION:** To accurately profile the step response of your VCO, the HP 5359A (supplying the external gate) must be time-synchronized with the HP 8112A (supplying the voltage step to your VCO). Perform the following steps to measure the time delay between these two instruments:

   a. Split the TRIG OUTPUT signal of the HP 8112A so that it goes to channel 1 of your digital oscilloscope (as well as to the HP 5359A EXT TRIGGER)

   b. Set the HP 8112A to NORM, PER = 1 μs

   c. Connect the HP 5359A 50Ω OUTPUT to channel 2 of your oscilloscope (temporarily disconnecting it from the GATE/ARM input of the HP 5361A)

   d. Set the HP 5359A delay to 0 nsec

   e. Measure the time delay between the rising edge of channel 1 and the falling edge of channel 2.

   This time delay is unique to your particular equipment and setup. **REMEMBER THIS NUMBER**; it is the first input requested by the computer program.

   f. Remove the scope from your set-up (move the cable going to the scope's channel 2 back to the HP 5361A GATE/ ARM input, and remove the cable between the scope's Input 1 and the HP 8112A).

Check the following table to ensure that the test signal falls within the operating range of the counter, and the manual settings on the pulse generator are correct.

VCO Test Signal	
Frequency	**500 MHz to 20 GHz**
Power	**-25 dBm to +7 dBm (-20 dBm to +7 dBm for frequencies above 12.4 GHz)**
HP 5359A Time Synthesizer	
Output Level	**0 to 2.5 V**
Output Polarity	**Positive, Comp**
Minimum Pulse Width	**20 nsec (manual mode); 100 ns (auto mode)**
Ext Enable Slope	**Positive**

Table 1. Operating Specifications

Program Description

■ The HP BASIC program listed at the end of this Application Note provides an interactive method of fully characterizing the frequency and timing parameters of your microwave VCO. It performs all measurements and outputs the results in both tabular and graphic form (if requested).

After initializing the test instruments and devices over the HP-IB, the program asks for the delay between the HP 8112A and the HP 5359A. This is dependent upon your particular instruments and set-up, and should be either measured (as specified on the previous page) or estimated fairly accurately. The program then does the following:

Frequency vs. Voltage Tuning Linearity.

(1) Allows the user to specify input parameters: minimum and maximum voltages to apply to the VCO, and desired voltage resolution (i.e., the size of the voltage steps between counter readings)

(2) Sets the pulse generator output to the minimum voltage

(3) Measures the resultant frequency out of the VCO

(4) Increases the pulse generator output level by the specified voltage increment

(5) Continues measuring the frequency and stepping the voltage until the maximum specified voltage is reached

(6) Calculates the linearity of the frequency response over the range of applied voltages

Step Response.

(1) Requests the user-specified parameters pertaining to step response and post tuning drift: low and high step voltages, time interval between each frequency measurement, and the number and size of the external gates used to profile the step response

For post tuning drift, requests the total time over which to monitor the VCO's output, and the time intervals at which to record the corresponding frequency

(2) Sets the pulse generator to output a train of voltage pulses as specified in step (1)

(3) Places the initial gate at the start of the step response and begins frequency measurement

(4) Observes enough signal pulses to obtain the specified frequency resolution, then records the measurement

(5) Continues to step the measurement gate through the VCO's step response, recording each measured frequency, until the total step response has been characterized

Post Tuning Drift.

(1) Begins measuring post tuning drift: steps the input voltage to the specified high voltage and begins the periodic frequency measurements

Graphics.

(1) Optionally graphs the results in four independent graphs (tuning linearity, modulation sensitivity, step response, and post tuning drift); (graphics subroutines do not appear in the enclosed listing, but are provided on the available software).

HP Basic Automated VCO Characterization Program*

```
10  !
30  !       AUTOMATED VCO CHARACTERIZATION
40  !       USING THE HP 5361A 20 GHz PULSE/CW
50  !             MICROWAVE COUNTER
60  !
70  !     Automatically characterizes a voltage controlled
80  !     oscillator (VCO). The following parameters are
90  !     measured, stored, and displayed in both tabular
100 !     and graphical form:
110 !         - TUNING LINEARITY (frequency out vs.
120 !           applied voltage)
130 !         - MODULATION SENSITIVITY (change in
140 !           frequency caused by incremental change
150 !           in voltage, versus voltage)
160 !         - STEP RESPONSE (frequency output at
170 !           closely spaced time intervals during
180 !           the VCO's response to input step change
190 !           in voltage)
200 !         - SHORT- AND LONG-TERM POST TUNING DRIFT
210 !           (frequency variations over time)
230 !
240 !
270 !            INITIALIZATION OF INSTRUMENTS
290 !
300 ASSIGN @Counter TO 714            ! * HPIB:  Counter = 14
310 ASSIGN @Synth TO 709              ! *        Time Synthesizer = 9
320 ASSIGN @Vsource TO 711            ! *        Voltage Source = 11
330 REMOTE @Counter
340 REMOTE @Synth
350 REMOTE @Vsource
370 DIM Freq(10000)                   ! * Dimension variables
380 DIM Fstp(10000)
390 DIM Fdrift(10000)
400 DIM Volt(10000)
410 DIM Deriv(10000)
420 DIM Tstp(10000)
430 DIM Tdrift(10000)
440 DIM X(10000)
450 DIM Y(10000)
470 Freq_max=1.0E-20                  ! * Initialize min and max  variables
480 Freq_min=1.0E+20
490 Deriv_max=1.0E-20
500 Deriv_min=1.0E+20
510 Fstp_max=1.0E-20
520 Fstp_min=1.0E+20
530 Fdrift_max=1.0E-20
540 Fdrift_min=1.0E+20
550 !
560 OUTPUT @Counter;"SET"
570 OUTPUT @Counter;"RESET"                 ! * Reset counter; set initial params:
580 OUTPUT @Counter;"FMRATE,NORMAL"         ! *   Normal FM rate
590 OUTPUT @Counter;"SAMPLE,HOLD"           ! *   Prepare for ext. trigger
600 OUTPUT @Counter;"RESOL,4"               ! *   10 kHz resolution
610 OUTPUT @Counter;"AUTO"                  ! *   Automatic counter acquisition
620 OUTPUT @Synth;"D0E-06"                  ! * Reset msmt. gate delay to zero
640 CLEAR SCREEN
```

**This software is offered at no charge as an example of the techniques described in this application note. Software performance is not warranted by Hewlett-Packard.*

```
660 PRINT "                AUTOMATED VCO CHARACTERIZATION
700 !
710 !                      TUNING LINEARITY MEASUREMENTS
740 !
750 !                             USER INPUTS
760 !
770 PRINT "What is the time delay between your HP 8112A Pulse Generator"
780 PRINT "  TRIG OUTPUT (source for your VCO control voltage) and your "
790 PRINT "  HP 5359A Time Synthesizer (supplying the external gate)  (nsec)?"
800 INPUT Inst_mismatch
830 PRINT "     TUNING LINEARITY:  FREQUENCY VS. VOLTAGE "
850 PRINT "         Enter the initial and final voltages you wish to"
860 PRINT "         apply to the VCO (Volts):"
870 INPUT Vmin,Vmax
880 PRINT Vmin,Vmax
900 PRINT "         What is the increment in voltage to be used for "
910 PRINT "          measuring the VCO's transfer characteristics (Volts):"
920 INPUT Vstep
930 PRINT Vstep
940 IF Vstep>(Vmax-Vmin) THEN Vstep=Vmax-Vmin
950 IF Vstep=0 THEN Vstep=1
980 PRINT "YOU HAVE CHOSEN TO CHARACTERIZE THE VCO IN ";Vstep;" VOLT STEPS"
990 PRINT "FROM ";Vmin;" TO ";Vmax;" VOLTS."
1020 !
1030 !                 DATA ACQUISITION
1050 I=0
1060 PRINT "VOLTAGE  FREQUENCY"
1070 FOR Voltage=Vmin TO Vmax STEP Vstep
1080   I=I+1
1090   OUTPUT @Vsource;"D0"
1100   IF Voltage=0 THEN OUTPUT @Vsource;"D1"
1110   OUTPUT @Vsource;"M2, HIL ";Voltage+1;"V,LOL ";Voltage;"V,L0,C0"
1120   WAIT 1
1130   Volt(I)=Voltage
1140   REPEAT
1150     OUTPUT @Counter;"TRIGGER"
1160     ENTER @Counter;Freq(I)
1170   UNTIL Freq(I)>0 AND Freq(I)<1.E+38
1180 PRINT Volt(I),Freq(I)
1190 NEXT Voltage
1200 Nomsmts=I                    ! * Store the number of measurements
1230 !              MODULATION SENSITIVITY CALCULATIONS
1240 !
1250 Denom=2*Vstep
1260 FOR J=2 TO Nomsmts-1
1270   Deriv(J)=Freq(J+1)-Freq(J-1)/Denom
1280 NEXT J
1310 !
1320 !               STEP RESPONSE MEASUREMENTS
1330 !
1360 !                          USER INPUTS
1400 PRINT "     VCO RESPONSE TO A STEP IN APPLIED VOLTAGE "
1420 PRINT "     Enter the lower and upper voltages of the desired"
1430 PRINT "      step in voltage (Volts):"
1440 PRINT ""
1450 INPUT Vinit,Vfinal
1460 PRINT Vinit,Vfinal
1470 Deltat=10
1480 PRINT "     Enter the time interval at which frequency measurements"
1490 PRINT "      should be taken (must be less than the settling time"
1500 PRINT "      of the VCO; DEFAULT=10 nsec) (nsec):"
```

```
1510 INPUT Deltat
1520 PRINT Deltat
1530 Deltat=Deltat/1000
1550 Width=100
1560 PRINT "Enter the desired gate width (minimum/default = 100 nsec) (nsec):"
1570 INPUT Width
1580 PRINT Width
1590 Width=Width/1000
1610 PRINT "      ... and the desired number of steps for frequency"
1620 PRINT "         determination (this number times the interval"
1630 PRINT "         requested above should be roughly equal to the"
1640 PRINT "         settling time of your VCO):"
1650 INPUT Nsteps
1660 PRINT Nsteps
1680 PRINT "YOU HAVE CHOSEN ";Nsteps;" STEPS OF ";Width;" MICROSECONDS EACH,"
1690 PRINT "WITH EACH STEP SPACED ";Deltat;" MICROSECONDS APART, IN ORDER TO"
1700 PRINT "PROFILE THE VCO'S RESPONSE TO A STEP IN APPLIED VOLTAGE "
1710 PRINT "FROM ";Vinit;" TO ";Vfinal;" VOLTS."
1750 !
1760 !                    DATA ACQUISITION
1770 !
1780 Period=3*(Width+(Nsteps*Deltat))
1790 IF Period<1 THEN Period=1
1800 IF Period<3*(Width+.1) THEN Period=3*(Width+.1)
1810 OUTPUT @Vsource;"M1"
1820 OUTPUT @Vsource;"HIL ";Vfinal;"V, LOL ";Vinit;"V, L0, C0, D0"
1830 OUTPUT @Vsource;"PER ";Period;"US, WID ";Period/3;"US"
1840 OUTPUT @Counter;"GATE,EXT"        ! * Set counter for external trigger
1850 OUTPUT @Synth;"W",Width;"E-06"    ! * Output gate width to synthesizer
1860 !
1870 PRINT "STEP    FREQUENCY"
1880 PRINT ""
1890 Dly2=Period-(Inst_mismatch/1000)
1900 FOR I=1 TO Nsteps                 ! * Step msmt gate through pulse:
1910   OUTPUT @Synth;"D",Dly2+(I-1)*Deltat;"E-06"! * Outputs delay to synth.
1920   Tstp(I)=I*Deltat
1930   OUTPUT @Counter;"FREQ"          ! * Measure frequency within gate
1940   REPEAT
1950     OUTPUT @Counter;"TRIGGER"
1960     ENTER @Counter;Fstp(I)
1970   UNTIL (Fstp(I)>0) AND (Fstp(I)<1.0E+38)
1980 PRINT I,Fstp(I)
1990 Fstart=Fstp(I)
2000 NEXT I
2020 !
2040 !              POST TUNING DRIFT MEASUREMENTS
2050 !
2080 !                          USER INPUTS
2090 !
2120 PRINT "        POST TUNING DRIFT MEASUREMENTS "
2140 PRINT "     What is the length of time over which you want to"
2150 PRINT "      measure the post-tuning drift (sec)?"
2160 INPUT Drift_time
2170 PRINT Drift_time
2180 PRINT "     What is the desired time interval between measurements"
2190 PRINT "      (between 0.01 and 86399.99 sec) (sec)?"
2200 INPUT T_interval
2210 PRINT T_interval
2220 PRINT "     What voltage do you want applied to the VCO (Volts)?"
2230 INPUT V_drift
2240 PRINT V_drift
2260 PRINT " YOU HAVE CHOSEN TO STEP THE INPUT VOLTAGE TO ";V_drift;" VOLTS,"
2270 PRINT " THEN MEASURE THE FREQUENCY EVERY ";T_interval;" SEC, FOR A "
2280 PRINT " TOTAL OBSERVATION TIME OF ";Drift_time;" SECONDS."
```

```
2300 !
2310 !              DATA ACQUISITION
2320 !
2330 OUTPUT @Vsource;"M2, HIL 0.1V, LOL 0.0V, L0,C0,D0"
2340 WAIT 1
2350 OUTPUT @Vsource;"M2, HIL ";V_drift+1;" V,LOL ";V_drift;"V, L0,C0,D0"
2360 OUTPUT @Counter;"GATE,INT"          ! * Set Counter
2370 OUTPUT @Counter;"SAMPLE,FAST"
2380 OUTPUT @Counter;"FREQ"
2400 WAIT T_interval                     ! * Wait one interval to settle
2410 IF T_interval=0 THEN T_interval=1
2420 No_intervals=INT((Drift_time-T_interval)/T_interval)+1
2430 T0=TIMEDATE                         ! * Initialize time
2440 PRINT "TIME         FREQUENCY"
2450 FOR I=1 TO No_intervals             ! * Take one frequency msmt.
2460   Tdrift(I)=I*T_interval
2470   REPEAT                            !  at each specified time
2480     ENTER @Counter;Fdrift(I)        !  interval
2490   UNTIL (Fdrift(I)>0) AND (Fdrift(I)<1.0E+38)
2500   REPEAT
2510   UNTIL (TIMEDATE-T0)>(I*T_interval)
2520 PRINT Tdrift(I),Fdrift(I)
2530 NEXT I
2560 FOR J=1 TO Nomsmts                  ! * Find min and max
2570   IF Freq(J)>Freq_max THEN Freq_max=Freq(J)
2580   IF Freq(J)<Freq_min THEN Freq_min=Freq(J)
2590 NEXT J
2610 FOR J=2 TO Nomsmts-1
2620   IF Deriv(J)>Deriv_max THEN Deriv_max=Deriv(J)
2630   IF Deriv(J)<Deriv_min THEN Deriv_min=Deriv(J)
2640 NEXT J
2660 FOR J=1 TO Nsteps
2670   IF Fstp(J)>Fstp_max THEN Fstp_max=Fstp(J)
2680   IF Fstp(J)<Fstp_min THEN Fstp_min=Fstp(J)
2690 NEXT J
2710 FOR J=1 TO No_intervals
2720   IF Fdrift(J)>Fdrift_max THEN Fdrift_max=Fdrift(J)
2730   IF Fdrift(J)<Fdrift_min THEN Fdrift_min=Fdrift(J)
2740 NEXT J
2790 ! ********************************************************************
2800 ! **          PRINT OUT TABLE OF RESULTS                    **
2810 ! ********************************************************************
2820 Deriv(1)=0.
2830 Deriv(Nomsmts)=0.
2850 CLEAR SCREEN
2860 PRINT "          *** SUMMARY OF VCO CHARACTERIZATION ***"
2880 PRINT ""
2890 PRINT "          TUNING LINEARITY and MODULATION SENSITIVITY"
2910 PRINT "
_____________________________________________________________________"
2920 PRINT "  VOLTAGE  FREQUENCY    dF/dV   VOLTAGE  FREQUENCY  dF/dV"
2930 PRINT "    (V)       (Hz)      (Hz/V)     (V)      (Hz)     (Hz/V)"
2940 PRINT "
_____________________________________________________________________"
2960 Format: IMAGE 2(XXXX,DD.DDD,XXX,DDD.3DE,XXX,MD.3DE)
2970 FOR J=1 TO INT((Nomsmts+1)/2)
2980   I=2*J-1
2990   PRINT USING Format;Volt(I),Freq(I),Deriv(I),Volt(I+1),Freq(I+1),Deriv(I+1)
3000 NEXT J
3030 PRINT "                TYPE 'CONTINUE' FOR NEXT TABLE..."
3040 PAUSE
3060 CLEAR SCREEN
```

```
3070 Format1:  IMAGE 2(XX,DDDD.DDDD,XX,MD.3DE)
3090 PRINT "                STEP RESPONSE"
3110 PRINT "
________________________________________________________________"
3120 PRINT "    TIME   FREQUENCY   TIME   FREQUENCY   TIME   FREQUENCY"
3130 PRINT "    (µS)     (Hz)      (µS)     (Hz)      (µS)     (Hz)"
3140 PRINT "
________________________________________________________________"
3160 FOR J=1 TO INT((Nsteps+2)/3)
3170   I=(3*(J-1))+1
3180   PRINT USING Format1;Tstp(I),Fstp(I),Tstp(I+1),Fstp(I+1),Tstp(I+2),Fstp(I+2)
3190 NEXT J
3220 PRINT "                 TYPE 'CONTINUE' FOR NEXT TABLE..."
3230 PAUSE
3250 CLEAR SCREEN
3260 Format2:  IMAGE 2(DDDD.DDDD,XX,MD.3DE)
3280 PRINT "               POST TUNING DRIFT"
3290 PRINT " "
3300  PRINT "________________________________________________________________"
3310 PRINT " TIME   FREQUENCY   TIME   FREQUENCY   TIME   FREQUENCY"
3320 PRINT " (SEC)     (Hz)     (SEC)     (Hz)     (SEC)     (Hz)"
3330  PRINT "________________________________________________________________"
3350 FOR J=1 TO INT((No_intervals+2)/3)
3360   I=(3*(J-1))+1
3370   PRINT USING Format2;Tdrift(I),Fdrift(I),Tdrift(I+1),Fdrift(I+1),Tdrift(I+2),Fdrift(I+2)
3380 NEXT J
5310 Finish: LOCAL 714            ! * Return instruments to
5320 LOCAL 709                    ! *  local control
5350 PRINT ""
5360 PRINT " ******** END OF VCO CHARACTERIZATION PROGRAM ********"
5370 END
```

For more information, contact the factory-authorized distributor or HP Sales Office listed here.

United States:
Hewlett-Packard Company
Laser Marketing, MS55/16
5301 Stevens Creek Blvd.
Santa Clara, CA 95052
Tel. 408-246-4300

Canada:
Hewlett-Packard Ltd.
6877 Goreway Drive
Mississauga, Ontario
L4V1M8
Tel. 416-678-9430

United Kingdom:
Hahn & Kolb Limited
Leicester Road
Rugby, Warwickshire CV21 1NY
Tel. 0788-77288

West Germany:
Hahn & Kolb
Borsigstrasse 50
7000 Stuttgart 30
Tel. 0711-2004-0

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S.I.M.C.I.S.A.
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91940 Les Ulis
Tel. 446-18-75

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Hibbert Machine Tool Service Co. Limited
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Kempton Park 1620
Tel. 011-975-7040

Europe:
Hewlett-Packard S.A.
7, rue du Bois-du-Lan
CH-1217 Meyrin 2
Geneva, Switzerland

Japan:
Yokogawa-Hewlett-Packard Limited
29-21, Takaido-Higashi 3-Chome
Suginami-ku, Tokyo 168
Tel. (03) 331-6111

Far East:
Hewlett-Packard Asia Headquarters
47th F, China Resources Bldg.
26 Harbour Road, Wanchai
Hong Kong

Other International Areas:
Hewlett-Packard Company
Intercontinental Headquarters
3495 Deer Creek Rd.
Palo Alto, CA 94304
U.S.A.

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