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HP References in this Application Note

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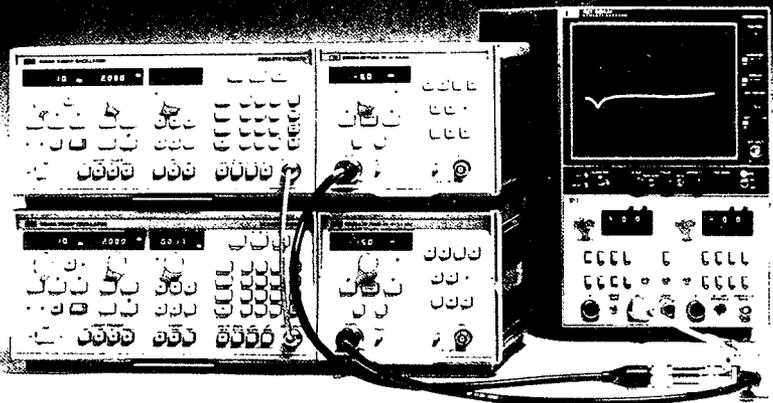
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Configuration of a Two-tone Sweeping Generator



application note 172-1

Introduction

Measurements that involve the design and testing of microwave frequency translators such as mixers or receiver front-ends require a local oscillator (LO) signal and a simulated received (RF) signal, separated by a designated intermediate frequency (IF). These signals are used for testing a variety of parameters such as conversion loss, RF and IF bandwidths, phase tracking, or amplitude tracking. Broad-band testing of these devices may be accomplished by taking CW measurements at discrete frequencies after manually tuning both the LO and RF signal sources. This method is time consuming and may result in the oversight of narrowband phenomena which can occur between discrete frequency points. Another method of testing these devices is performed by using two tracking swept sources to cover the required frequency range. Swept testing can shorten test time dramatically, in addition to providing continuous coverage of the required frequency range.

This application note describes two swept systems that will produce the required RF and LO signals, offset from each other by the necessary IF. One system is comprised of two HP 8350A Sweep Oscillators connected together in a Master/Slave configuration. This system offers RF plug-ins that collectively cover a frequency range of 10 MHz to 26.5 GHz, depending on the plug-in used. The frequency offset (IF) of this system does not have any constraints except that the IF bandwidth must be sufficiently wide to accommodate the tuning non-linearity of the plug-in. A second system employs the same basic equipment but adds greater offset precision by phase-locking the "Slave" at an offset frequency to the "Master," permitting measurements with narrow IF bandwidths. In addition, the HP 8620C Sweep Oscillator may be configured in this manner to provide a Two-tone Source, as described in Appendix B. This system will operate over RF frequencies between 2 and 18 GHz with an offset frequency range between 30 and 500 MHz.

Either of these systems can serve as the source in a multitude of applications. With the measurement configuration described in Figure 1, phase or amplitude tracking between two mixers may be measured using a Two-tone Source as a stimulus and a vector network analyzer to receive and compare the mixer outputs. In this configuration two mixers may be tuned to form a matched pair.

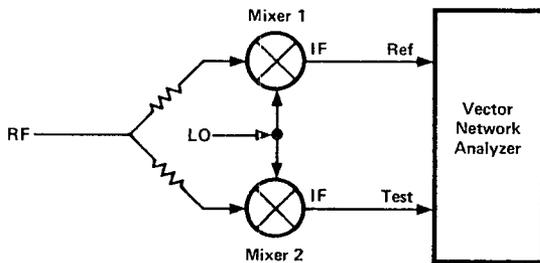


Figure 1. Mixer Test Set Up

Output characteristics of the IF port may be tested for a variety of translators (i.e., receiver front ends, mixers) with a spectrum analyzer and a Two-tone Source (see Figure 2). Using this configuration, a swept Two-tone Source with a constant IF may be used to determine the frequency response of a device, and with various measurements this can be related to parameters such as noise and harmonics.

A common measurement made on mixers is conversion loss! This measurement may easily be made using a tracking Two-tone Source for stimulus and a scalar network analyzer as the receiver (see figure

$$\left(\frac{P_{IF}}{P_{RF}} \right)$$

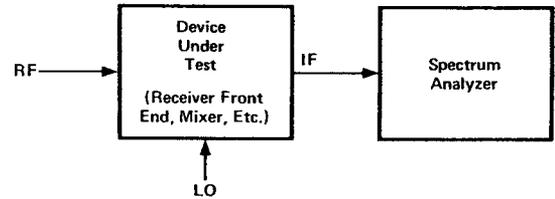


Figure 2. IF Signal Analysis Test Set Up

3). A scalar network analyzer using AC detection is particularly useful for this measurement as it does not display the effects of unmodulated signals such as LO feedthrough.

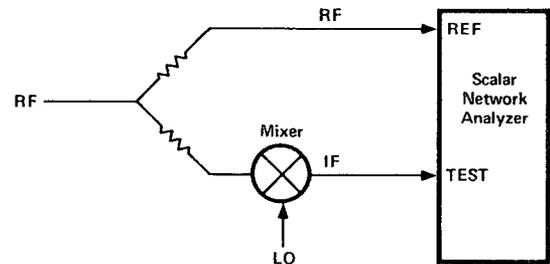


Figure 3. Mixer Conversion Loss Measurement

Since there are so many various applications for a tracking source, this application note will not attempt to go into detail on specific test set-ups. Instead this note will concentrate on the configuration of the tracking source, as well as the procedures for using it.

Basic Two-tone Source

Block Diagram and Frequency Configuration

In this configuration, one sweeper is designated as the "Master"; in this capacity all the parameters are set as a normal sweeper. The second sweeper is designated as the "Slave." The sweep ramp of the "Master" is then used to externally sweep the "Slave" which has been adjusted to the proper frequency offset. In order to accept this sweep ramp the "Slave" sweep mode controls must be set to external sweep. After the frequency offset has been entered on the "Slave," the remaining frequency settings must be set identically to the "Master's." To coordinate the various sweep signals such as retrace and bandswitching, a Sweep Control Cable is attached to the programming connector. The result of this configuration produces one sweeper output tracking the other, differing in frequency from each other by the desired offset.

Basic Two-tone System Set Up

SUGGESTED EQUIPMENT

- (2) HP 8350A Sweep Oscillator mainframes with RF plug-ins to cover the required frequency range

- (1) BNC cable
- (1) Sweep Control Cable, HP part number: 08350-60050 (or see Appendix A for cable assembly)

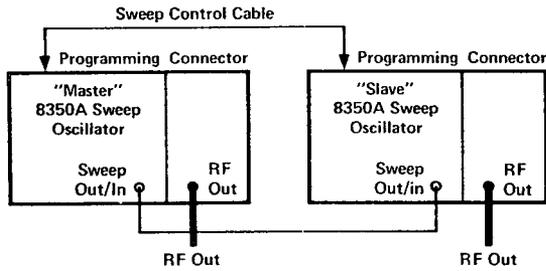


Figure 4. Basic Two-tone System Block Diagram

SYSTEM SET UP AND OPERATION

1. Connect the equipment as shown in Figure 4.²
2. Check the frequency accuracy of each sweep oscillator and calibrate using the frequency calibration adjustment (if available on plug-in).

8350A SWEEP OSCILLATOR AND RF PLUG-INS

3. Set the 8350A "Slave" Sweep Mode to "EXT" sweep and the 8350A "Master" to "TIME."
4. Adjust the 8350A "Slave" to the desired offset by pressing "SHIFT" "VERNIER" and entering the offset value (or IF).
5. Set the "Master" and "Slave" START and STOP frequencies to the desired frequency range. For CW operation, set the CW frequencies of the "Master" and "Slave" to the same frequency.
6. Turn the RF blanking OFF on the "Master."

Performance Characteristics

The Basic Two-tone System operates over an extremely broad frequency range, from 10 MHz to 26.5 GHz. The frequency offset (IF) of this system can be 0 to 26.5 GHz with the only constraint being that the IF frequency must accommodate the plug-in frequency range and the IF bandwidth of the device under test must accommodate the tuning non-linearity of the plug-ins. These plug-in specifications may be found in the associated Operating and Service Manual. For example, the HP 86290B 2-18.6 GHz plug-in has a sweep linearity of 8 MHz for single band sweeps (2-6.2 GHz, 6-12.4 GHz and 12-18.6 GHz) and 30 MHz for multiband sweeps (2-18.6 GHz).

The absolute frequency characteristics of the "Master" and "Slave" sweepers are independent of the system. To improve the frequency accuracy, a counter may be used to count the "Master" and "Slave" START and STOP frequencies.

The output power of the system is determined by the specific plug-ins. For tests over a wide range of signal levels a step attenuator

may be used to increase the power control range of either or both signals. This step attenuator may be located internally in the plug-in or externally in the signal path. For best tracking, the sweep time should be greater than 100 msec, except when using multiband plug-ins (i.e., HP 86290A/B/C, 83525A, 83592A, 83590A, 83594A, 83595A) in which case the sweep time should be no less than 100 msec per band in use.

Two-tone Source With Phase-locked Offset

For more demanding applications a Two-tone Source with Phase-locked Offset provides improved offset (IF) accuracy over the Basic Two-tone Source previously described. Like the Basic Two-tone Source, this system designates one sweep oscillator as a "Master" and the other as a "Slave" (see Figure 5). The sweep ramp of the "Master" is then used to externally sweep the "Slave" which has been adjusted to the desired offset. A Sweep Control Cable is attached to the programming connector to coordinate the sweep signals.

In order to improve the offset (IF) accuracy a phase-lock scheme is used. Directional couplers internal to the HP 8709A Opt K30 Phase-lock Controller sample the two sweep oscillator signals, which are then mixed, producing a difference frequency approximately equal to the desired IF. This difference frequency is then mixed with that of the reference oscillator which is 20 MHz above the required IF. The resultant difference frequency is compared in the HP 8709A Opt H08 Synchronizer with a 20 MHz standard. This 20 MHz standard may either come from the synchronizer's internal crystal oscillator or, for more stability, an external 20 MHz standard may be injected into the synchronizer through a rear panel injection lock BNC connector. The synchronizer outputs a correction voltage driving the phase-lock input of the "Slave" sweeper to phase-lock the offset between the two sweepers. This results in the "Slave" sweeper being offset in frequency with an offset (IF) accuracy equal to the accuracy of the reference oscillator and the 20 MHz standard, allowing measurements on systems with narrow IF bandwidths.

For more demanding applications a Two-tone Source with Phase-locked Offset provides improved offset (IF) accuracy over the Basic Two-tone Source previously described. Like the Basic Two-tone Source, this system designates one sweep oscillator as a "Master" and the other as a "Slave" (see Figure 5). The sweep ramp of the "Master" is then used to externally sweep the "Slave" which has been adjusted to the desired offset. A Sweep Control Cable is attached to the programming connector to coordinate the sweep signals.

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SUGGESTED EQUIPMENT

- (2) HP 8350A Sweep Oscillator mainframes with RF and Microwave plug-ins to cover the required frequency range
- (1) HP 8709A Opt H08 Synchronizer
- (1) HP 8709A Opt K30 Phase-lock Controller
- (1) Bandpass filter (see text of System Set Up and Operation Step 2)
- (1) Reference Oscillator (e.g., HP 8640A/B Signal Generator, 8656A Signal Generator)
- (2) RF Interconnect Cables (For Rack Mounted Systems) HP Part Number 08709-60089 (upper) and HP Part Number 08709-60103 (lower)
- (2) Sweep Control Cables, HP Part Number 08350-60050 (or see Appendix A for cable assembly)
- (3) BNC Cables

²Note: When the BNC is connected between the "Master" and "Slave" Sweep Out/In, E003 will occur after Instrument Preset. This is normal and is a result of the additional sweep input. Press [START] to return the front panel to normal operation and continue the system setup.

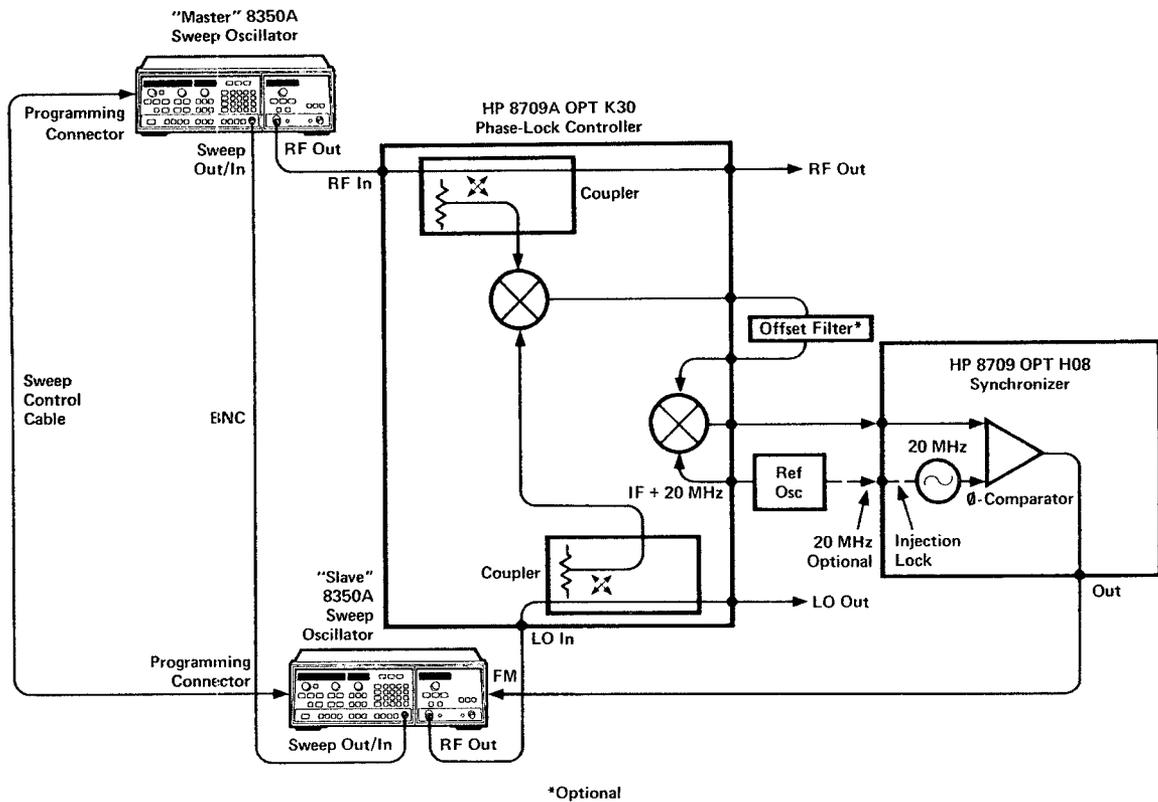


Figure 5. Two-tone System with Phase-Locked Offset Block Diagram

SYSTEM SET UP AND OPERATION

1. Connect the equipment as shown in Figure 5³

2. Selection of the Offset Bandpass Filter: Select a bandpass filter with a 10 MHz, 3 dB bandwidth centered at the desired offset frequency with a passband insertion loss of 3 dB and rejection at 20 MHz of 30 dB. Insert this filter between the OFFSET FILTER connectors on the rear of the HP 8709A Opt K30. The Offset Bandpass Filter is not required for many test applications. The need for the Bandpass Filter is determined by the system phase-lock stability.

HP 8350A SWEEP OSCILLATOR AND RF PLUG-INS

3. When using HP 86200 series plug-ins: Set the rear panel FM/NORM/PL switch to "PL" (phase-lock). On some 86200 series plug-ins, this switch is inside the plug-in and should be set to "FM2" (see plug-in Operating and Service Manual).
4. When using HP 83500 series plug-ins: Set the dual in-line package (DIP) switches on board A3 for 6 MHz/V FM sensitivity by setting switch 5 to the "1" position.
5. Make sure that RF BLANK pushbutton switch is OFF on the "Master" front panel.

6. Set the sweep time to 100 msec for single band plug-ins. When using multiband plug-ins, adjust the sweep time so that it is 100 msec per band in use during the sweep.

7. Check the frequency accuracy of each sweep oscillator and calibrate using the frequency calibration adjustment (if available on the plug-in).

8. Set the designated 8350A "Slave" to "EXT" sweep and the 8350A "Master" to "TIME" sweep.

9. Adjust the 8350A "Slave" to the desired offset by pressing "SHIFT" "VERNIER" and enter the desired frequency offset.

10. Set the "Master" and "Slave" to the same sweep settings to cover the desired frequency range. For CW operation, set the "Master" and the "Slave" to the same frequency.

HP 8709A OPT H08 SYNCHRONIZER

11. Set the rear panel MOD SENS switch to 6.0 MHz/V.

HP 8709A OPT K30 PHASE-LOCK CONTROLLER

12. Select UPPER MASTER/LOWER SLAVE or UPPER SLAVE/LOWER MASTER with pushbutton switch. This determines whether the higher or lower frequency sweeper is to serve as the "Master."

³Note: When the BNC is connected between the "Master" and "Slave" Sweep Out/In, E003 will occur after instrument Preset. This is normal and is a result of the additional sweep input. Press [START] to return the front panel to normal operation and continue the system setup.

REFERENCE OSCILLATOR

13. Set the frequency to the desired offset plus 20 MHz.
14. Set the Power Level to +5 dBm.

HP 8350A SWEEP OSCILLATOR AND RF PLUG-INS

15. On the "Slave," adjust the offset frequency until the synchronizer unlocked light goes out and the phase error indicator is approximately centered. Now the offset frequency is phase-locked with the reference oscillator.

RF Frequency Characteristics of the System

This system will operate at RF frequencies between 2 and 18 GHz with offset frequencies in the range of 30 to 500 MHz. These limits are established by the couplers and mixers within the 8709A Opt K30 Phase-lock Controller.

The offset frequency characteristics of the system are almost entirely dependent on the reference oscillator and the synchronizer. For example, with a 100 MHz IF and the HP 8640B Signal Generator as the reference, the offset accuracy will be approximately 1100 Hz. This is due primarily to the accuracy of the synchronizer's internal 20 MHz reference. If an external 20 MHz reference is used to injection lock the synchronizer (via the rear panel injection lock BNC connector), or if the internal reference is precalibrated, the offset accuracy will approach 100 Hz. The stability of the offset frequency may also be improved to that of the reference (approximately 0.05 ppm/hr with the 8640B) by injection locking the synchronizer with a precision 20 MHz signal.

The decision as to what reference oscillator is required for the application will be affected by the phase noise requirements of the offset. Some examples: the HP 8640B Signal Generator (500 kHz to 512 MHz) SSB phase noise in a 1 Hz bandwidth at a 20 kHz offset from the carrier is 120 to 140 dB down depending on its output frequency, while the HP 8656A Signal Generator (100 kHz to 990 MHz) is 115 to 127 dB down depending on the frequency. The same specification for the HP 8660A/C Synthesizer with the HP 86602B plug-in (1-1300 MHz) is approximately 105 dB down. If the application requires only one specific IF offset frequency, a fixed tuned crystal oscillator may be used for the reference.

The absolute frequency characteristics of the "Master" sweeper are basically independent of the rest of the system. Consult the specification of the plug-in use. The absolute frequency characteristics of the "Slave" are equal to those of the "Master" plus the offset frequency characteristics.

The output power is determined by the specific plug-in minus the insertion loss of the phase-lock controller, which is approximately 0.5 dB at 2 GHz and 2 dB at 18 GHz. Internally leveled flatness of the RF outputs is equal to the specified flatness plus the frequency response of the phase-lock controller, which is typically ± 0.2 dB over octave ranges and ± 0.8 dB over 2-18 GHz. This may be improved through external leveling by putting the leveling couplers at the HP 8709A Opt K30 RF and LO output ports. The input power to the 8709A Opt K30 must fall between 0 dBm and 3 dBm for normal operation. Because the phase-lock controller needs relatively high signal levels, external attenuation may be needed in the received signal (RF) path to the device under test.

Isolation between the two outputs is typically 60 dB. For this system the sweep time must be greater than 100 msec except when using a multiband plug-in, in that case the sweep time should be no less than 100 msec per band in use.

Additional Capabilities

Both Two-tone systems may easily be turned into automatic systems. The Basic Two-tone System or the Two-tone System with Phase-locked Offset (constant frequency offset) only need the addition of an HP-IB⁴ compatible controller to become completely auto-

matic. For more accuracy, the HP 5343A Opt. 011 Microwave Counter can be used to automatically count the START and STOP frequency of the "Master" or "Slave" while sweeping. The Two-tone System with Phase-locked offset may be automated for variable frequency offsets by adding an HP-IB Controller, an HP-IB programmable reference oscillator (such as the HP 8660A/C Opt. 005 Synthesized Signal Generator or the HP 8656A Synthesized Signal Generator) and an HP-IB switch (e.g., HP 59307A) to switch in the appropriate Offset Filter (if Offset Filters are required for system stability). These systems would then allow a very time consuming series of tests to be performed with a minimum of effort.

Where amplitude modulation is necessary (i.e., when using the HP 8755C Network Analyzer that uses AC detection) both types of Two-tone sources may be modulated. The Basic Two-tone System may easily be modulated by pressing the "MOD" pushbutton ON on either the "Master" or the "Slave." The Two-tone System with Phase-locked Offset requires that the RF or LO output of the phase-lock controller be modulated with an external modulator.

For general purpose applications, either or both of the sweepers may be disconnected from the system and used in standard sweep testing.

Appendix A

Configuration of a Two-tone Source

The Sweep Control Cable uses six pins of the 8350A rear panel Auxiliary Programming Connector to coordinate the sweep signals of the two sweep oscillators (see Figure 6). This connector mates with 25-Pin D series male connectors which can be obtained from ITT Cannon part number DBM-25P. A complete cable assembly can be obtained by ordering HP Part Number 08350-60050.

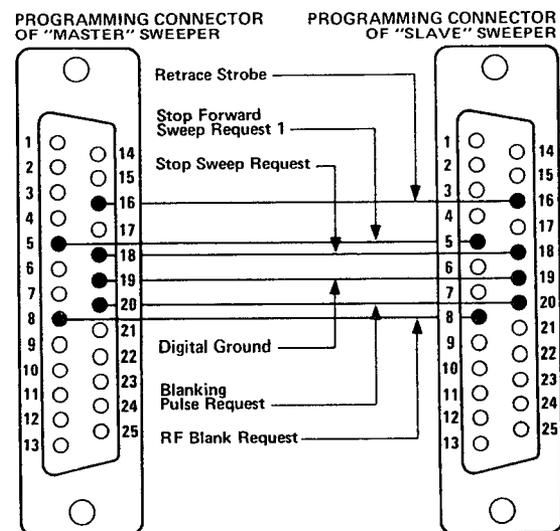


Figure 6. Sweep Control Cable Assembly

Appendix B

Configuration of a Two-tone Source Using the 8660A Sweep Oscillator

The theory of operation for using an 8620C in a Two-tone source is similar to that of the Two-tone Source with Phased-locked

⁴HP-IB refers to the Hewlett-Packard Interface Bus which is equivalent to the IEEE 488 standards.

Offset previously described. The primary difference between the systems lies in the method of setting up the frequency offset and tracking between the "Master" and the "Slave." The 8620C and the 8709A both require special modification in order to work as a Two-tone system. The following text describes the necessary equipment and set-up required to configure and operate a Two-tone 8620 system. The performance characteristics are the same as those for the Two-tone System with Phase-Locked Offset.

SUGGESTED EQUIPMENT

- (2) HP 8620C Opt H40 Sweep Oscillator mainframes with RF plug-ins to cover the required frequency range
- (1) HP 8709A Opt H08 Synchronizer
- (1) HP 8709A Opt K50 Phase-lock Controller
- (1) Bandpass filter (see text)
- (1) Reference Oscillator (e.g., HP 8640A/B Signal Generator, 8656A Signal Generator)
- (2) RF Interconnect Cables (For Rack Mounted Systems) HP Part Number 08709-60022, HP Part Number 08709-60023
- (2) Frequency Control Cables, HP Part Number 08709-60032
- (1) BNC Cable

SYSTEM SET UP AND OPERATION

Connect the equipment as shown in Figure 7.

Offset Bandpass Filter: Select a bandpass filter with 10 MHz, 3 dB bandwidth centered at desired offset frequency, passband insertion loss of 3 dB, and rejection at ± 20 MHz of 30 dB. Insert between OFFSET FILTER connectors on rear of 8709A-K50. The Offset Bandpass Filter is not required for many test applications. The need for the Bandpass Filter is determined by the system phase-lock stability.

8620C and RF Plug-ins: Set rear panel FM/NORM/PL switch to PL (Phase-lock). On some 86200 series plug-ins, switch is inside the plug-in; set to FM2. Set rear panel 1 kHz Square Wave and RF Blanking to OFF. Select proper bands with Master Band Select Lever. Set sweep time to 100 msec (except 86290A/B/C in Band 4 set to approx. 500 msec).

Synchronizer (8709A-H08): Set MOD SENS switch to 6.0 MHz/Volt.

Controller (8709A-K50): Select UPPER MASTER/LOWER SLAVE or UPPER SLAVE/LOWER MASTER with pushbutton switch. This determines which sweeper will be the controller.

Reference Oscillator: Set frequency to desired offset + 20 MHz. Set power level to +5 dBm.

Set the "Master" to cover desired frequency range. Adjust controller Gain control fully clockwise and adjust the OFFSET control for band in use until synchronizer UNLOCKED light goes out and phase error indicator is approximately centered. The "Master" may then be set to sweep across any or all of the desired range and the "Slave" will follow at the desired offset frequency below the "Master."

*86300 series plug-ins are not recommended in this application.

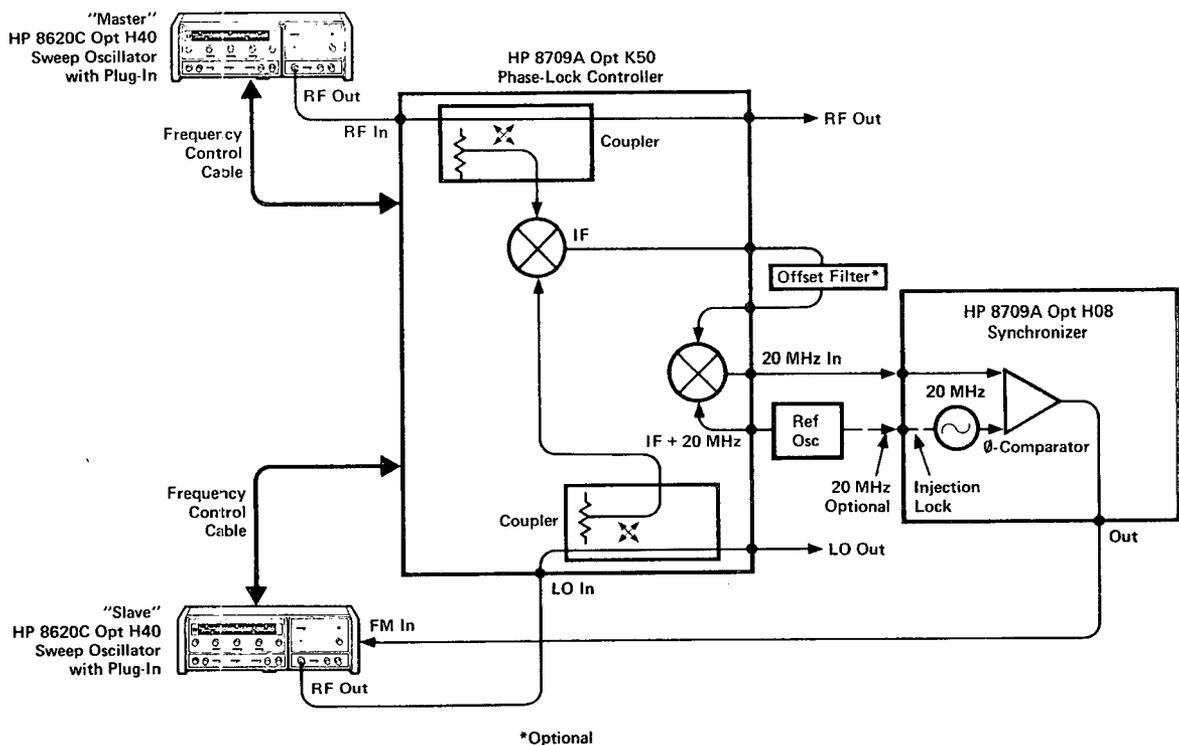


Figure 7. Two-tone Sweeping Generator Block Diagram

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