APPLICATION NOTE 49

MEASURING THE FREQUENCY OF SMALL 10-100 MC SIGNALS

INTRODUCTION

This application note describes a method of measuring frequency in the 10 to 100 mc range with high sensitivity, good stability and ease of operation and adjustment. The system is useful when signal levels are too low for direct counting on the ⓗⓟ Model 524 Electronic Counter with a Model 525A Frequency Converter or for pulsed or fm deviation measurements where direct counting is not applicable.[1] This system makes possible frequency measurement of signals with levels as low as 100 microvolts.

DESCRIPTION OF EQUIPMENT

The system contains an easily constructed mixer assembly consisting of a crystal and low-pass filter, an ⓗⓟ Model 524 Electronic Counter, Model 606A Signal Generator, Model 466A AC Amplifier and an oscilloscope.

DISCUSSION OF THE SYSTEM

The system block diagram is shown in figure 1. In this system an unknown frequency is compared with the harmonic of the 606A Signal Generator using transfer oscillator techniques. Since frequencies up to 10.1 mc can be measured accurately with the Model 524 Frequency Counter, the unknown frequency can be determined by multiplying the fundamental by the appropriate harmonic number.

The mixer assembly generates harmonics of the 606A Signal Generator frequency and mixes them with the unknown frequency. The low-pass filter attenuates all signals above audio frequencies so that rf signals from the Model 606A and unknown signal frequencies do not appear on the oscilloscope. The audio difference frequency between the unknown frequency and the harmonic of the 606A Signal Generator is amplified by the 466A and displayed on the oscilloscope screen. When the 606A harmonic and the unknown frequency are at zero beat, the pattern on the oscilloscope screen will go through a null. The frequency is then read on the Model 524 Frequency Counter and multiplied by the appropriate harmonic number as discussed under the heading "Determining the Unknown Frequency and Harmonic Number".

ACCURACY

Measurement accuracy depends upon 1) counter accuracy, 2) signal to noise ratio and 3) the operator's comparison accuracy.

Typical system accuracy is about 2.5 parts in 10^7, however, an experienced operator can achieve accuracy of one part in 10^7. The Model 524C/D has a stability specification of 5 parts in 10^8 per week.

[1] See also Application Note 1, Measuring Frequency Modulated Signal; Application Note 2, Frequency Measurement of Low-Level Signal and Application Note 3, Measurement of RF Pulse Carrier Frequency; Hewlett-Packard Co., Palo Alto, California.

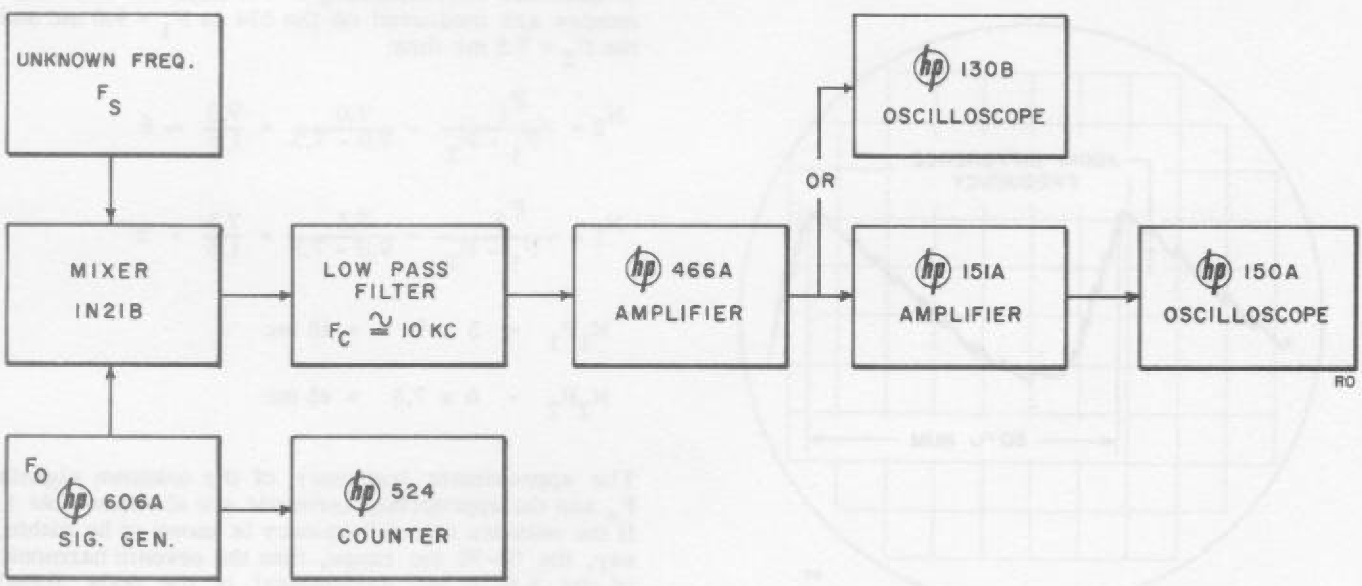

Figure 1. Block Diagram of System using Model 606A Signal Generator as a Transfer Oscillator

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TEST PROCEDURE

1) Construct the mixer and low-pass filter assembly as shown in the Appendix.

2) The equipment setup is shown in figure 1.

3) Set the oscilloscope controls as follows:
Vertical Sensitivity, 20 millivolts/cm.
Sweep, 500 microseconds/cm.
Sync Mode to Line.

4) For unknown signals greater than 1 millivolt, no particular crystal selection is necessary. For signals below 1 mv see the discussion of "Typical Crystal Sensitivities at Various Frequencies" in the appendix.

5) Some noise should appear on the screen. Adjust the vertical sensitivity of the oscilloscope so that the noise amplitude is about 1/4 cm. Depending on the location and the equipment, there may be a certain amount of power line hum present on the screen. The oscilloscope when synchronized on the line frequency will give a display similar to figure 2.

6) Set the 606A output to 1 volt on the output meter.

7) Adjust the 606A frequency dial so that the harmonic zero beats with the unknown signal frequency and read the 606A fundamental frequency on the 524 counter. Adjust the oscilloscope gain to keep the beat note within view of the screen. When the beat note is as small as the noise amplitude, concentrate on the thickness of the noise trace for the beat variation. With a little practice one can readily detect the beat note through the noise and 60 cycles. The unknown frequency is determined by multiplying the 524 Frequency Counter reading by the harmonic number. The following procedure is used to find the appropriate harmonic number.

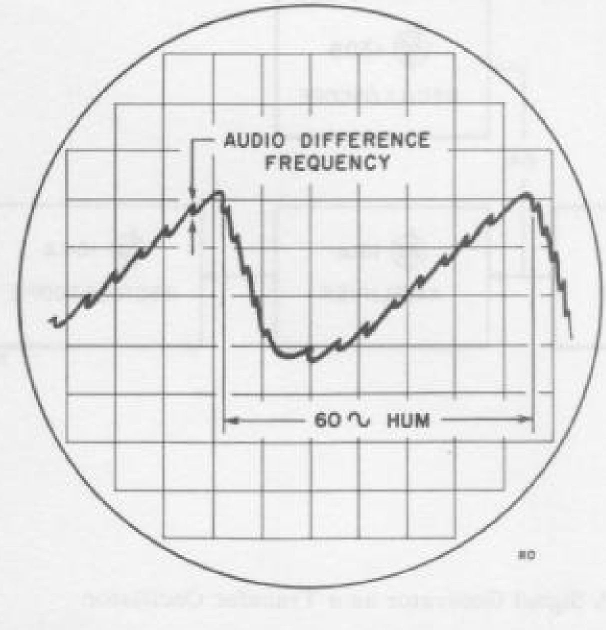

Figure 2. Oscillogram of Difference Frequency near Zero Beat of Unknown Signal and Model 606A Signal Generator Harmonic

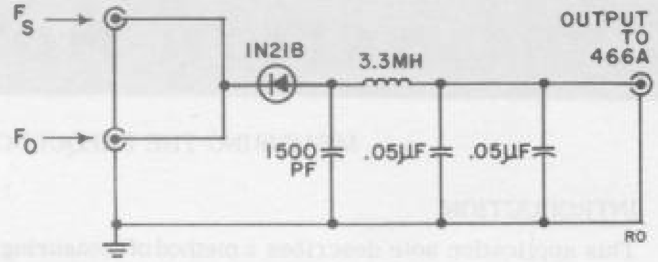

Figure 3. Schematic Diagram of Crystal Mixer and Low Pass Filter

DETERMINING THE UNKNOWN FREQUENCY AND HARMONIC NUMBER The approximate frequency may already be known with enough accuracy to determine the harmonic number. If the unknown frequency cannot be approximated, the harmonic number can easily be calculated. The 606A Signal Generator's fundamental is measured for two adjacent zero-beat conditions, and the harmonic numbers are calculated from the equations:

$$N_1 = \frac{F_2}{F_1 - F_2} \quad \text{and} \quad N_2 = \frac{F_1}{F_1 - F_2}$$

Where N_1 and N_2 are the harmonic numbers of F_1, the higher, and F_2, the lower, of the two adjacent fundamental frequencies.

Greater care must be used when measuring higher frequencies because of the progressively closer spacing and decreasing strength of the haromincs.

Consider the following example of the determination of the harmonic number when two adjacent harmonic frequencies have been measured. If the fundamental frequencies corresponding to two adjacent 606A harmonics are measured on the 524 as $F_1 = 9.0$ mc and the $F_2 = 7.5$ mc then:

$$N_2 = \frac{F_1}{F_1 - F_2} = \frac{9.0}{9.0 - 7.5} = \frac{9.0}{1.5} = 6$$

$$N_1 = \frac{F_2}{F_1 - F_2} = \frac{7.5}{9.0 - 7.5} = \frac{7.5}{1.5} = 5$$

$$N_1F_1 = 5 \times 9 = 45 \text{ mc}$$

$$N_2F_2 = 6 \times 7.5 = 45 \text{ mc}$$

The approximate frequency of the unknown signals F_s and the appropriate harmonic are shown in table 1. If the unknown signal frequency is known to be within, say, the 60-70 mc range, then the seventh harmonic of the 8.6-10 mc fundamental of the 606A Signal Generator should be used. If the signal is in the 30-40 mc range then the fourth harmonic of the 7.5-10 mc 606A Signal Generator fundamental should be used. As the harmonic number gets higher, the signal gets weaker and crystal sensitivity decreases.

Approximate Frequency of Unknown Signal
F_s and Appropriate Harmonic

TABLE 1

F_s Unknown Frequency	F_o (606A) (Measured by hp 524)	Harmonic
10 - 20 mc	5 - 10 mc	2
20 - 30	6.6 - 10	3
30 - 40	7.5 - 10	4
40 - 50	8.0 - 10	5
50 - 60	8.3 - 10	6
60 - 70	8.6 - 10	7
70 - 80	8.7 - 10	8
80 - 90	8.9 - 10	9
90 - 100	9 - 10	10

Typical Crystal Mixer Sensitivities
at Various Frequencies

TABLE 2

Frequency (mc)	Selected 1N21B	Average 1N21B
10 - 20	40 μv	100 μv
20 - 30	50 μv	150 μv
30 - 40	60 μv	200 μv
40 - 50	60 μv	200 μv
50 - 60	60 μv	200 μv
60 - 70	80 μv	300 μv
70 - 80	90 μv	300 μv
80 - 90	90 μv	300 μv
90 - 100	100 μv	300 μv

APPENDIX

SELECTING CRYSTAL DIODES FOR MAXIMUM SENSITIVITY

When the signal is below 1 millivolt in amplitude, select mixer crystals for maximum sensitivity according to the following procedure.

1) The output voltage range of the 606A is adjusted for best S/N ratio typically over the range of approximately .7 to 1.5 volts.

2) Try different crystal mixers in the circuit until the most sensitive one is found. Typical crystal sensitivities are shown in table 2.

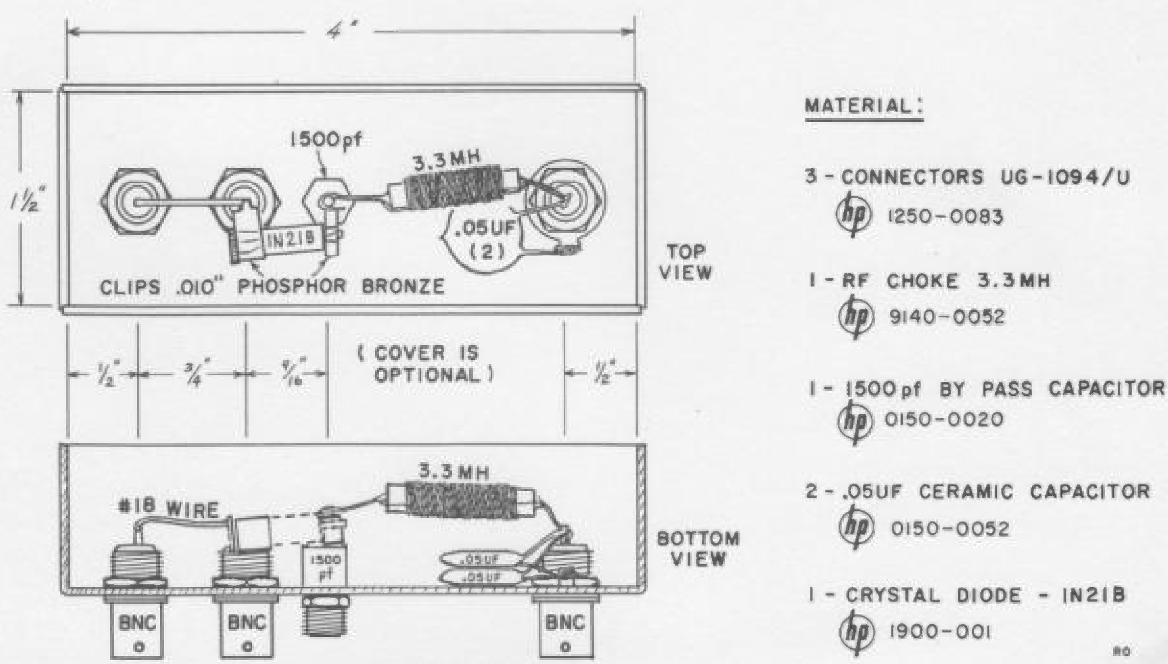

Figure 4. Construction Details of Crystal Mixer and Low Pass Filter

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