

COMMUNICATIONS

Engineering Bulletin

By: John Hatchett
Roger Janikowski,
Applications Engineering

VCO and VCXO Designs Using The MC12060 And MC12061 Oscillator Circuits

The primary use of the MC12060 and MC12061 integrated circuits is in applications providing a highly stable signal of precise frequency in which the basic operating frequency is established by an external crystal. However, through the use of a tuning diode and suitable circuitry, these integrated circuits can also function as voltage controlled oscillators (VCOs) and voltage controlled crystal oscillators (VCXOs).

Typical circuit designs and measured performance are given in Figures 1 and 2 for VCOs and in Figures 3 through 7 for VCXOs. These circuits provide insight into several design approaches. Other tuning ranges and linearity improvement could be expected using other tuning diodes, tuning diode combinations or, in the case of VCXOs, crystals cut to exhibit certain "warpability" specifications. All evaluation data was taken from the sine wave outputs of the ICs, pin 2 or pin 3, using the test circuit of Figure 8. The 680 ohm resistor to ground facilitates driving a 50 ohm load.

Since both linearity and frequency range are largely functions of the tuning diode, the dc control voltage (V_R) range should be chosen to fit the diode characteristics. Extremely low or high V_R values (relative to the diode specifications) must be avoided for best linearity.

Only frequencies above those obtained using a crystal by itself can be realized by adding a tuning diode in series with the crystal as in Figures 3 and 5, that is, the frequency can only be pulled higher. When a tuning diode plus an inductance are added as in Figure 6, however, frequency can be pulled both higher or lower allowing improvement in linearity as well as tuning range.

Spectrum analysis (Figures 4 and 7) was made with a Hewlett-Packard HP8553B/52B analyzer using the technique of shifting IF gain to prevent analyzer internal noise from affecting the observed oscillator signal. The signal both before and after increasing IF gain is shown in each case. The shifted display (peak-missing) is the most accurate where analyzer internal noise levels are being approached.

Since spectrum displays of this nature are a function

of the measurement bandwidth, relative bandwidth settings must be taken into account to assess performance. The following spectrum analyzer correction factors should be also applied:

1. Add 2.5 dB to noise level to correct for detector and log shaping characteristics.
2. Subtract $10 \log_{10} 1.2 = 0.8$ dB from the noise level to convert from Gaussian-shaped bandwidth (indicated on the figures as BW) to a "noise power" (rectangular) bandwidth.

The signal spectrum expected for bandwidths other than those used in the measurements can be approximated using the factor $10 \log_{10} \frac{BW \text{ measured}}{BW \text{ desired}}$ to adjust for the change in bandwidth. It is fairly common to refer signal noise level to a 1 Hz bandwidth.

Applying this adjustment at 100 Hz from the 10 MHz signal of Figure 7a shows the noise level to be:

$$-82 \text{ dB} + 2.5 \text{ dB} - 0.8 \text{ dB} - 10 \log_{10} \frac{10 \text{ Hz}}{1 \text{ Hz}} = -90.3 \text{ dB}$$

(referred to a 1 Hz noise-power bandwidth). This "close-in" noise performance is significantly better than that of the MC1648 VCO operating as an L-C oscillator. In a similar manner, the adjusted noise level would be -117 dB at 100 kHz from the signal in Figure 7c, a "noise floor" level which compares closely to that of the MC1648 L-C oscillator.

Spectral purity for the MC12060/MC12061 devices operating as VCOs (Figures 1 and 2) is much degraded from that of VCXO operation and is also worse than that of the MC1648 L-C VCO.

*Motorola MC12060/12560 and MC12061/12561 integrated circuits are designed for use with an external fundamental series resonant crystal. Complementary sine wave, complementary ECL and single ended TTL outputs are available. Complete technical specifications for these ICs can be found on the device data sheet and additional information in application note AN-756 and engineering bulletin EB-59.

FIGURE 1
MC12060 VCO Frequency Versus Control Voltage

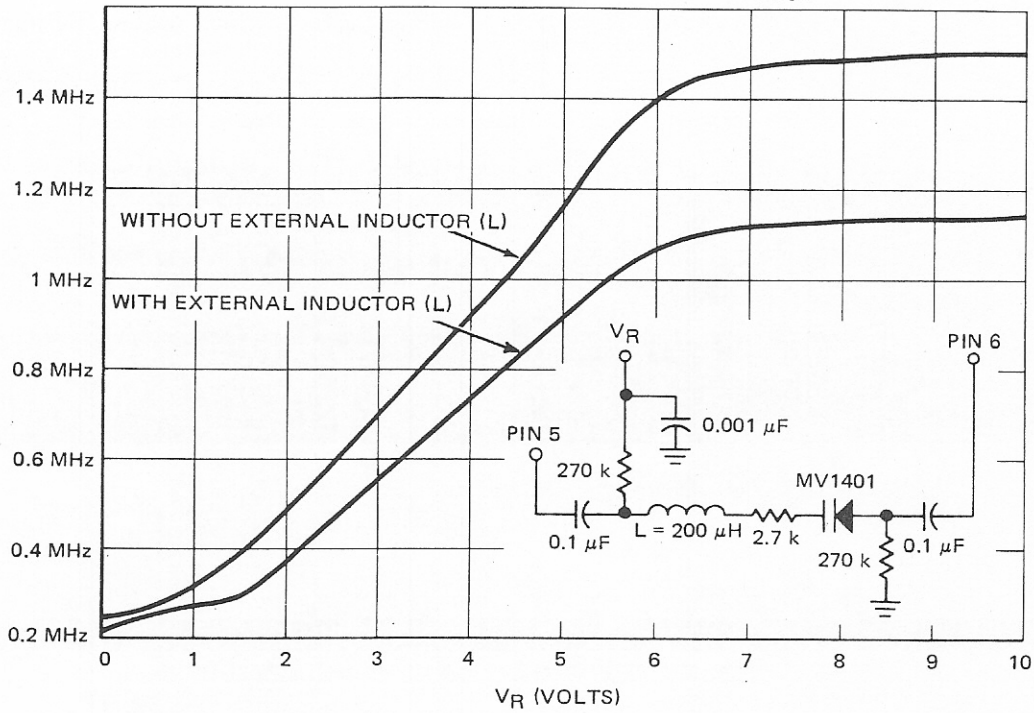


FIGURE 2
MC12061 VCO Frequency Versus Control Voltage

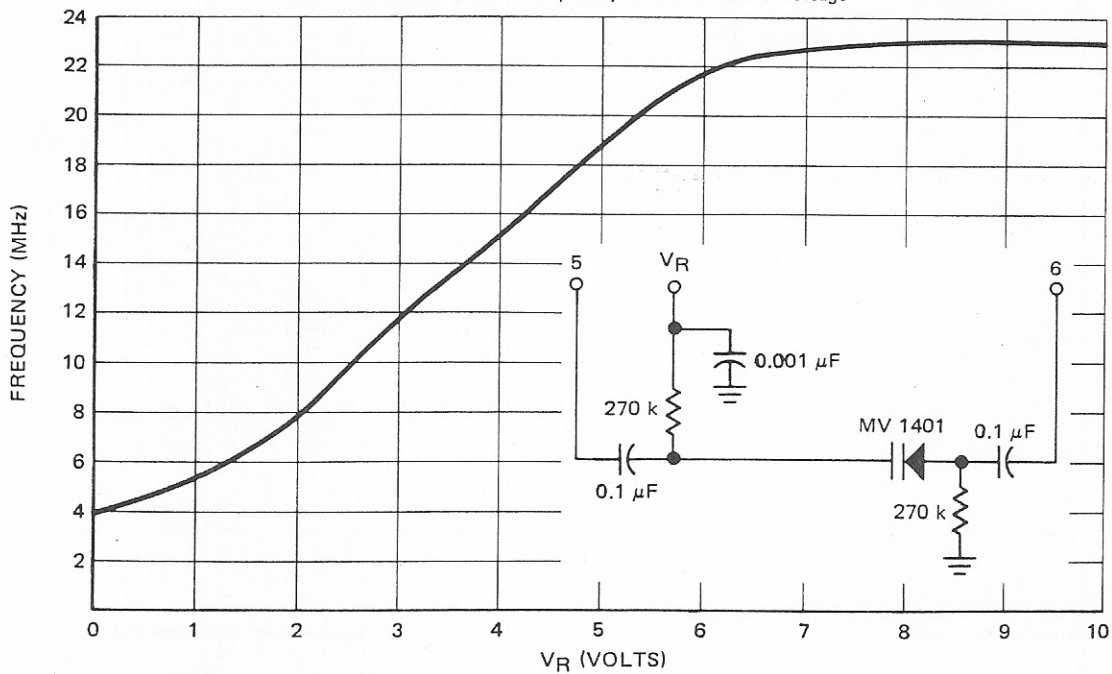


FIGURE 3
MC12060 VCXO Frequency Pull Versus Control Voltage

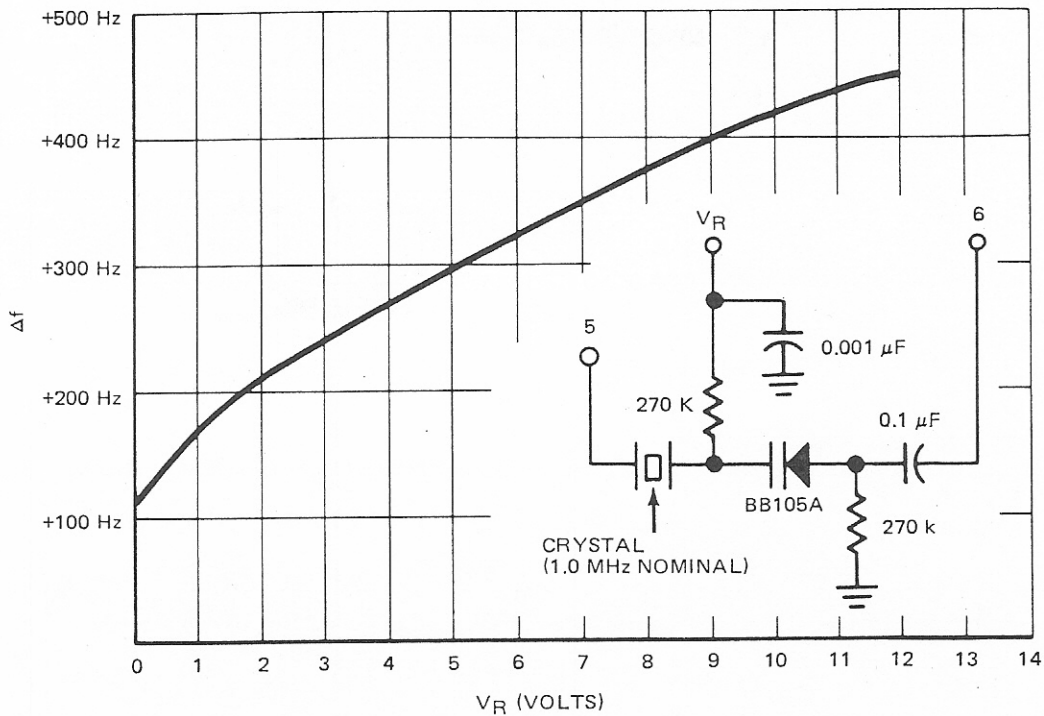
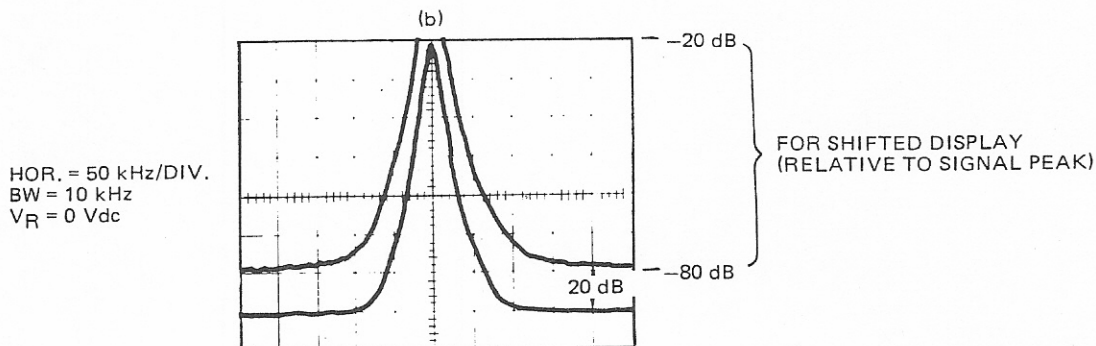
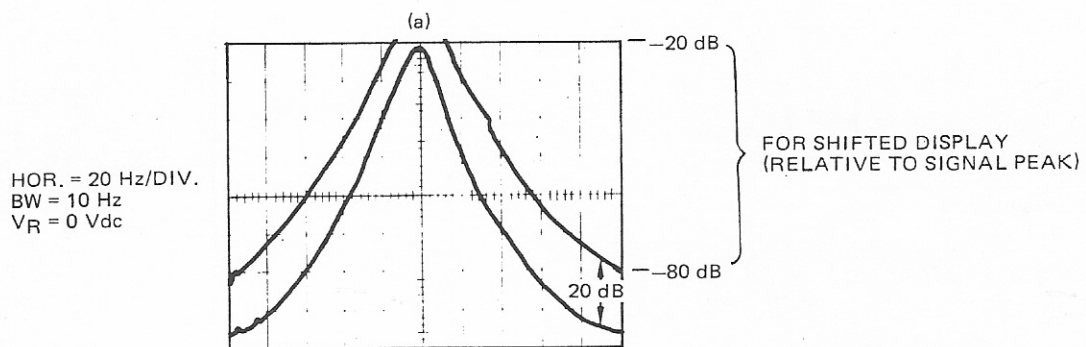


FIGURE 4
Spectrum Analyzer Information for the
1 MHz VCXO of Figure 3



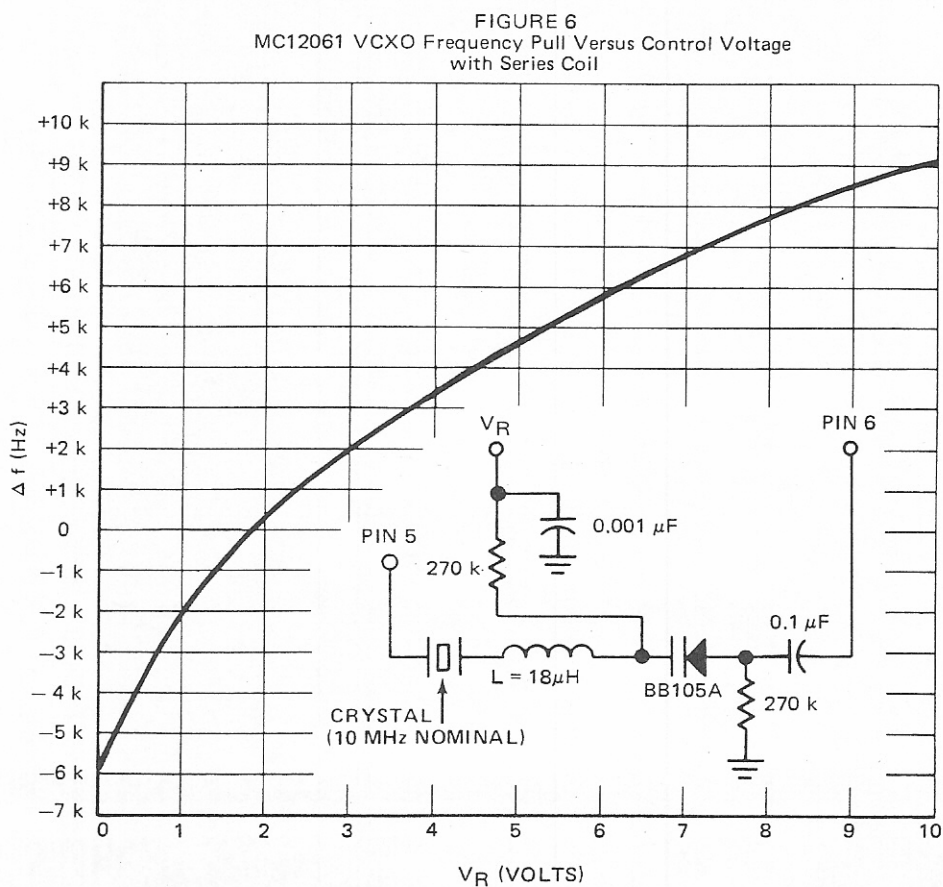
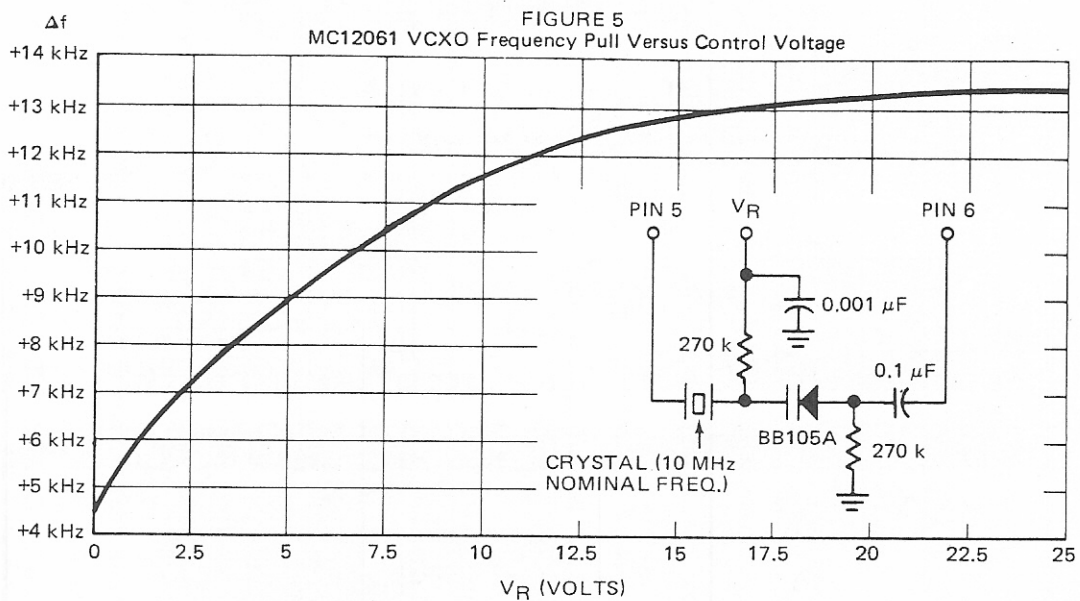


FIGURE 7
Spectrum Analyzer Information for
The 10 MHz VCXO of Figure 6

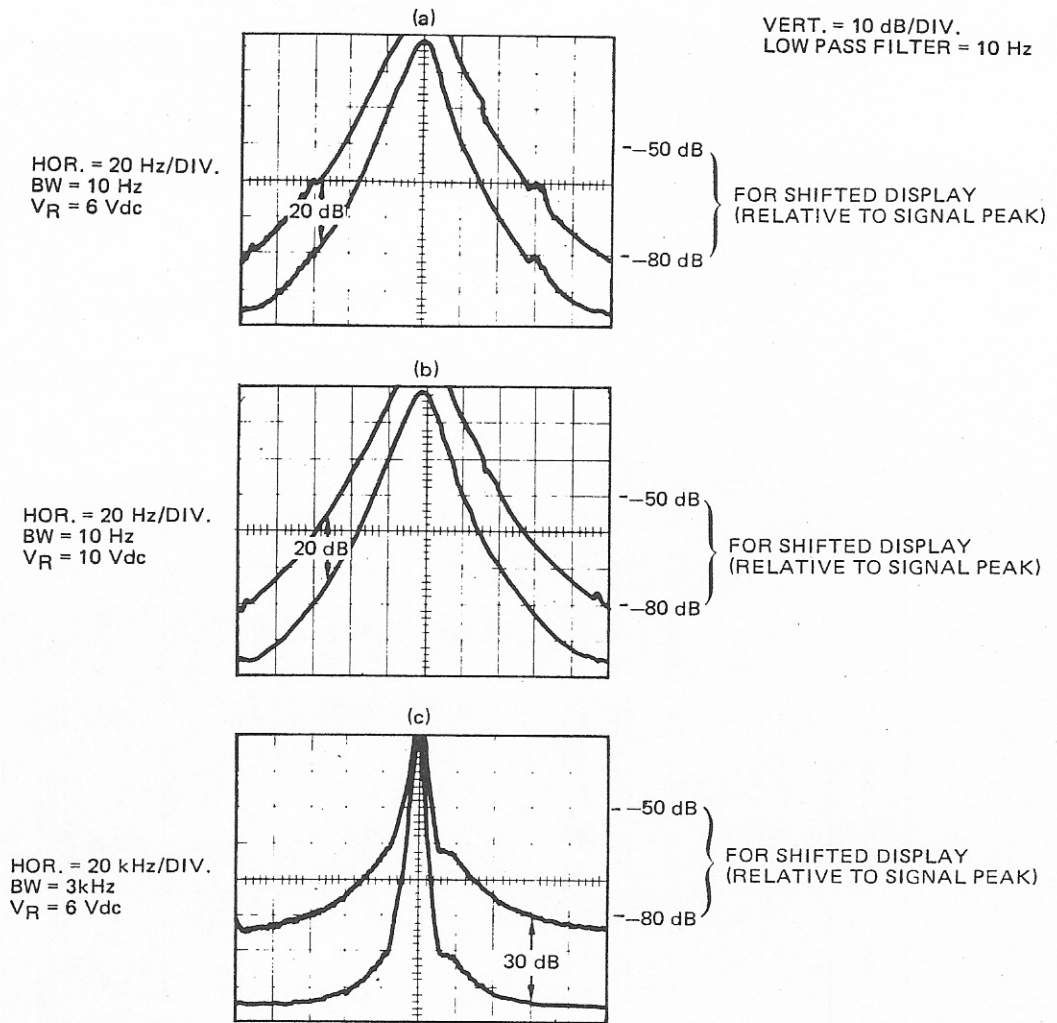
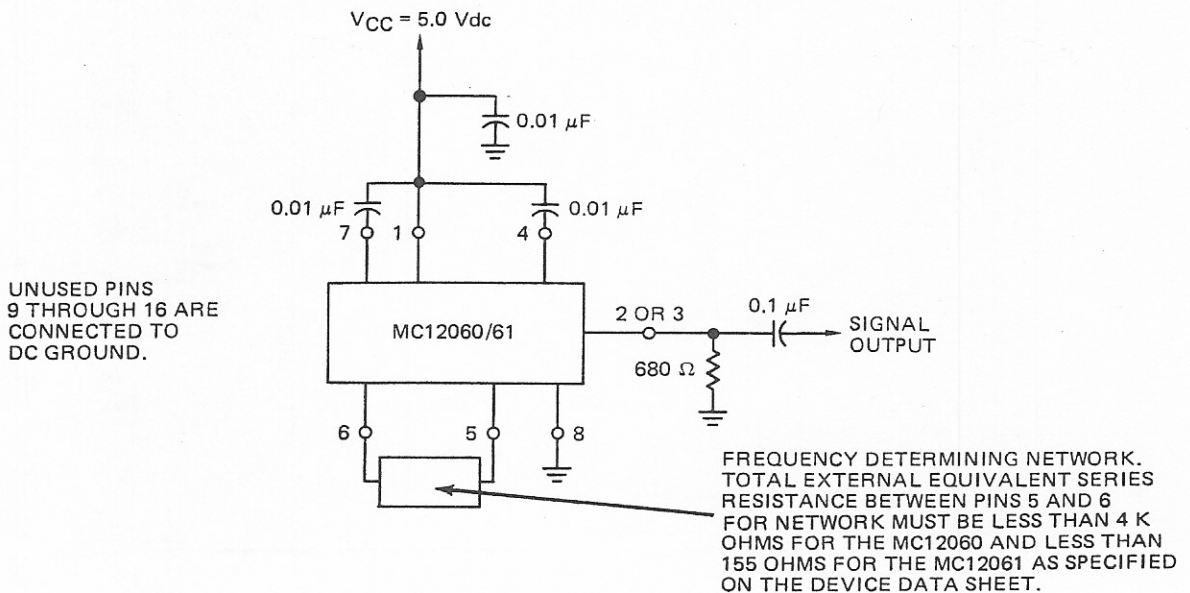


FIGURE 8
VCO and VCXO Evaluation Circuit



Circuit diagrams external to Motorola products are included as a means of illustrating typical semiconductor applications; consequently, complete information sufficient for construction purposes is not necessarily given. The information in this Engineering Bulletin has been carefully checked and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.



MOTOROLA *Semiconductor Products Inc.*

P. O. BOX 20912 / PHOENIX, ARIZONA 85036