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Designing Crystal Oscillators with Modern CMOS Gates

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APPLICATION NOTE

INTRODUCTION

Designing a crystal oscillator with modern CMOS gates is difficult with the limited information available. The designer has many families to choose from: 4000 series, HCMOS, LCX, and VHC, for starters. The selection of the logic family depends on the system voltage and frequency of operation.

Designing a crystal oscillator using gates instead of buying a pre-packaged device that includes all the active components provides the following benefits:

- Save Money
- Control the Parameters that are Critical to the Design

In order to save money, the designer has to be willing to undertake the design and understand the tradeoffs. By doing this, he also is able to take control of critical parameters such as frequency, accuracy, and stability.

This article will only be concerned with the fundamental mode operation. Today's crystals can be purchased with fundamental modes up to about 30 MHz. These techniques also work well for ceramic resonators.

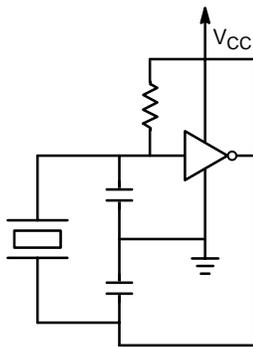


Figure 1. Crystal Oscillator Using Unbuffered CMOS Gate

Theory of operation: in nearly all cases, using a gate as an oscillator entails causing the gate to go into class “A” or biased between the on and off state. This is accomplished by placing a large resistor, between 10 and 20 MΩ from the output to the input. The mode of operation is the “Pierce” crystal oscillator (Amateur Radio Handbook, 1968).

This circuit can be considered a grounded source transistor, with Capacitors to ground. The input (gate) and output (drain) are “floating.” This circuit has been around in vacuum tube form for many years, and is just a modern version of the circuit. To implement this circuit, an “unbuffered” inverter is usually used (see Figure 1). Devices such as the MC74VHCU04 or MC74LCXU04, available from ON Semiconductor, will provide stable operation from below 1 MHz to above 20 MHz, from 2–5 volts operation. Since there are six active inverters in each 14-pin package, the designer is encouraged to use at least one of the devices as a buffer. The unbuffered gate, such as a VHCU04, contains just one P-Channel, and one N-Channel device. Since there is just one complementary pair, this is only one transistor gate delay. These devices are fabricated in 0.6μ CMOS and have significant Class A gain for any crystal application up to 100 MHz or more. If the designer needs a circuit to operate between 7 and 18 volts, the MC14049UB from the 4000 series of Metal Gate CMOS makes a good choice. The designer has to be careful not to make demands on the circuit that exceed the maximum frequency capabilities of this family (~ 4–10 MHz).

In all cases, the designer needs to be aware that it is possible to damage the crystal with over-active excitation. By using the unbuffered inverters and a series resistor (see Figure 2), in the VHC or Metal gate series, the designer can be confident that there will not be too much drive. A test to determine whether appropriate drive is being obtained is described in the High-Speed CMOS Data book, DL129/D. The designer builds a prototype of the circuit and applies V_{CC} through a variable supply. If the frequency shifts very slightly higher when the supply voltage is varied, the design is valid. If the frequency decreases or becomes unstable, a resistor should be added to the circuit.

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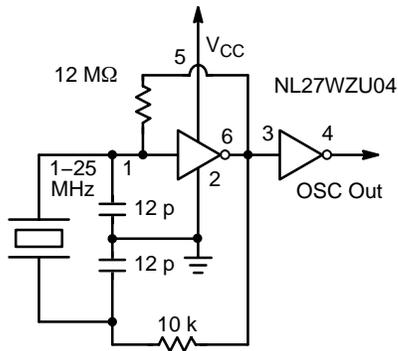


Figure 2. Complete Crystal Oscillator Circuit

The above circuit will serve as a good starting point for a design. The capacitor values may need to be altered to suit the crystal. This same design could be done using standard 14 pin devices, e.g. MC74HCU04 – just remember to tie off unused inputs.

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