AND8141/D

Unbuffered Gates for Crystal Oscillators

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APPLICATION NOTE

CMOS logic devices have been used for many years as oscillators. Many designers have shied away from trying to design their own oscillator for fear issues that are hard to foresee. One issue is determining whether an oscillator will “start−up”. Another issue is the size of the logic circuit. Whereas in the past, a package of 4 or 6 gates or inverters in a small SOIC package was considered very small, today’s wireless/handheld products require a much smaller footprint or board area than a 14 pin package.

To overcome the issues with start−up and size the ON Semiconductor has come out with a nearly perfect solution in the NL27WZU04. The “U” implies an unbuffered gate. Standard inverters such as the NL17SZ04 consists of 3 pairs of P−N channel devices wired together to form a single inverter (Figure 1). This structure makes for an excellent inverter with very strong output drive and excellent digital characteristics. Unfortunately, this structure is less reliable when used in an oscillator section due to its enormous AC gain. The “U” device overcomes this objection and makes for an ideal oscillator or other AC (gain) application. As we can see in Figure 2, the inverter is simpler, with only standard “04” gate one P−N channel pair. With only one section, the device is much more usable in an AC application**.** The reader might assume that with only one stage, the resulting inverter is weak; however, this is not the case. The standard “04” inverter is certainly a bit stronger, but the “U04” is certainly usable as an inverter. The NL27WZU04 buffer can drive a 12 mA load, when operating at 3.0 V, compared to the NL27WZ04 that can drive 24 mA. The unbuffered device is a bit faster than the standard device, since the inverter only needs to get through one level of logic, instead of three.

In order to use an unbuffered inverter as an amplifier or oscillator, there needs to be a bias established. The simplest and the best solution is a feedback resistor from output to input. A large value resistor of several megohms is needed. The output will be forced to maintain itself at the input threshold value. This point will be the only stable point. The resistor value should be small enough to establish the bias and large enough to permit the inverter to function with some gain. The rest of the circuitry is just a Pierce crystal oscillator. This particular article will deal only with the fundamental mode of crystal operation. It is certainly possible to have a similar circuit function at 150 MHz or more in an overtone mode, however, this can be tricky and this application will be left to the reader.

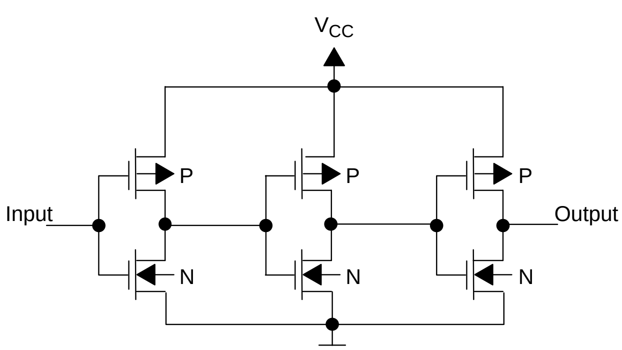

Figure 1.

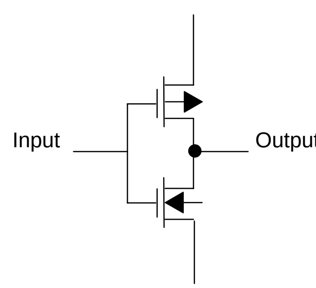

Figure 2.

Final Circuit

We have laid out a board to function at 10 MHz. The NL27WZU04 has two inverters, one is used as the oscillator, and the second is used as a driver. The NL27WZU04 is rated from 1.65 to 5.5 V. An empirical test for start−up might be to sweep the supply voltage slowly, from zero volts and note where oscillation begins. A stable circuit will start−up at about 1.5 V or less and function normally from 1.5 V to 5.5 V with very little change in frequency. If the circuit does not start properly, then select a new value of feedback resistor. The shunt capacitor should match the loading required by the crystal manufacturer, taking into account the input and out C of the device as well. The reader will also note that we have included a second resistor. Many designers leave this out; however, it prevents damage to the crystal. The value for this resistor empirically has been determined to be about 10 kΩ. Another empirical test for this R value, is to build a test board and select a value, for example, 10 kΩ, set the operating voltage at the desired level, e.g. 2.5 V, now vary the DC level ±20%. The oscillator frequency should shift a small amount and should be continuous without large abrupt shifts in frequency. If the frequency shift is small and non−abrupt, the value is all right. If the frequency jumps and is erratic with small shifts in supply voltage, then try increasing the value of R by 20−50%. Repeat this process until the oscillator is stable.

Figure 3 shows a working schematic and layout of an oscillator capable of driving almost any circuit that is stable and known to have good startup characteristics. The reader is invited to use this as a starting point of an oscillator design, and create his own design properly suited to his own voltage, frequency and drive requirements. The shunt capacitance should be the value recommended by the crystal manufacturer, including the shunt value for the NL27WZU04. The resistor values in Figure 3 are good starting points and the two empirical tests should be performed.

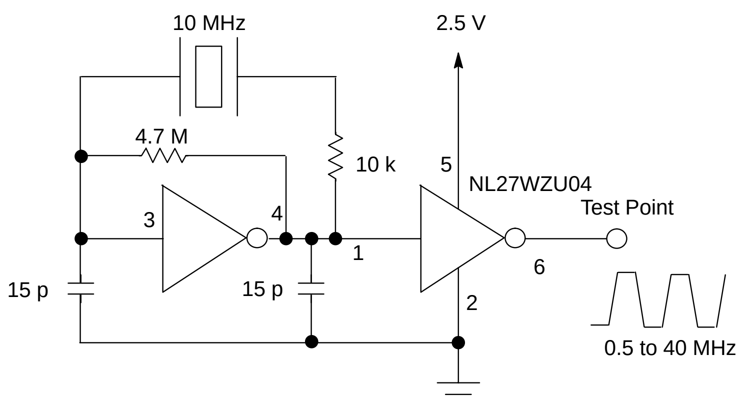

Figure 3.

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