

# ON Semiconductor

## Is Now

# onsemi™

To learn more about onsemi™, please visit our website at  
[www.onsemi.com](http://www.onsemi.com)

---

**onsemi** and **onsemi** and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.

## Unbuffered Gates for Crystal Oscillators

Prepared by: Fred Zlotnick  
ON Semiconductor



ON Semiconductor®

<http://onsemi.com>

### 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.

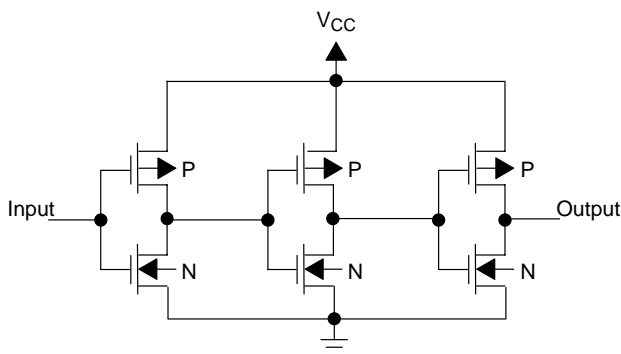


Figure 1.

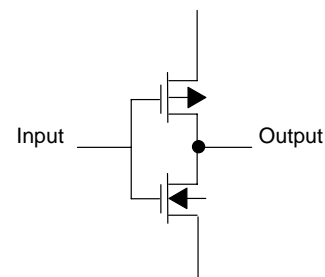


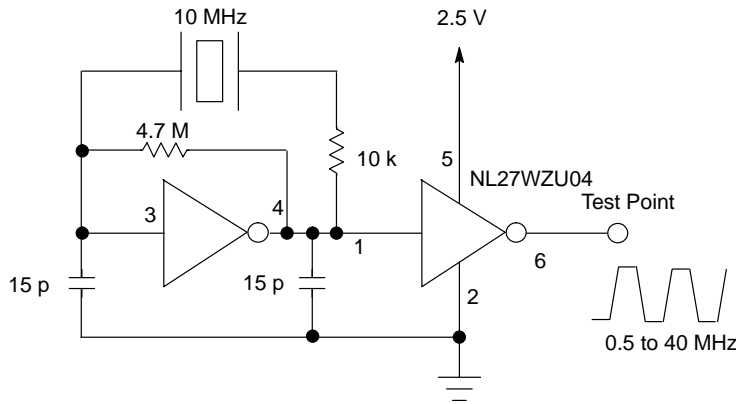
Figure 2.

**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.**

ON Semiconductor and  are registered trademarks of Semiconductor Components Industries, LLC (SCILLC). SCILLC reserves the right to make changes without further notice to any products herein. SCILLC makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does SCILLC assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. "Typical" parameters which may be provided in SCILLC data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. SCILLC does not convey any license under its patent rights nor the rights of others. SCILLC products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the SCILLC product could create a situation where personal injury or death may occur. Should Buyer purchase or use SCILLC products for any such unintended or unauthorized application, Buyer shall indemnify and hold SCILLC and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that SCILLC was negligent regarding the design or manufacture of the part. SCILLC is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

**PUBLICATION ORDERING INFORMATION**

**LITERATURE FULFILLMENT:**  
 Literature Distribution Center for ON Semiconductor  
 P.O. Box 5163, Denver, Colorado 80217 USA  
**Phone:** 303-675-2175 or 800-344-3860 Toll Free USA/Canada  
**Fax:** 303-675-2176 or 800-344-3867 Toll Free USA/Canada  
**Email:** orderlit@onsemi.com

**N. American Technical Support:** 800-282-9855 Toll Free USA/Canada  
**Japan:** ON Semiconductor, Japan Customer Focus Center  
 2-9-1 Kamimeguro, Meguro-ku, Tokyo, Japan 153-0051  
**Phone:** 81-3-5773-3850

**ON Semiconductor Website:** <http://onsemi.com>  
**Order Literature:** <http://www.onsemi.com/litorder>  
 For additional information, please contact your local Sales Representative.