# Application Note

# External Oscillator Solutions with GreenPAK

## AN-CM-233

### Abstract

*This application note discusses two oscillator circuits which use a GreenPAK chip with external components: a sub-uA 1 kHz RC oscillator circuit and a 32.768 kHz Pierce oscillator.*

*This application note comes complete with design files which can be found in the References section.*

# Contents

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# 1 Terms and Definitions

| | |
|---|---|
| IC | Integrated circuit |
| CMOS | Complementary mixed oxide semiconductor |
| Crystal | Piezoelectric material that produces an electrical signal as it mechanically resonates |
| NMOS | N-channel MOSFET |
| OE | Output enable |
| RC circuit | Resistor-capacitor circuit |

# 2 References

For related documents and software, please visit:

GreenPAK™ Programmable Mixed-Signal Products | Renesas

Download our free GreenPAK™ Designer software [1] to open the .gp files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Renesas Electronics provides a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the IC.

[1] GreenPAK Designer Software, Software Download and User Guide, Renesas Electronics

[2] AN-CM-233 External Oscillator Solutions with GreenPAK.gp, GreenPAK Design File, Renesas Electronics

[3] GreenPAK Development Tools, GreenPAK Development Tools Webpage, Renesas Electronics

[4] GreenPAK Application Notes, GreenPAK Application Notes Webpage, Renesas Electronics

[5] SLG46121, Datasheet, Renesas Electronics

[6] SLG46620, Datasheet, Renesas Electronics

[7] SLG46533, Datasheet, Renesas Electronics

[8] Ramon Cerda, *Pierce-Gate Crystal Oscillator*, Microwave Product Digest, 2008

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# 3 Introduction

Some applications require oscillators not already served by the on-chip oscillators inside a GreenPAK IC. This application note describes two designs wherein a few passive external components can be used as an oscillator, which is connected to a GreenPAK. The first design is a low-power RC oscillator. The second is a low-power 32 kHz crystal oscillator circuit. In both cases, the GreenPAK design is similar; GPIO pins are used and further internal components are not required.

# 4 Low Power (sub-µA) RC Oscillator

An RC oscillator, using external components , allows the user to adjust frequency by adjusting the component values. RC oscillators can easily be made with any GreenPAK chip, but dual-rail chips additionally can make such RC oscillators very low power, down to sub-µA levels, by allowing the use of a resistor to limit the power drawn from the secondary rail. The following design implements an example with the dual-rail SLG46121V, but any dual-rail GreenPAK could be used.

## 4.1 Circuit Design

Fundamentally, a typical oscillator consists of an inverting gain with feedback. In GreenPAK, this can be implemented with just a pin-to-pin connection as shown in Figure 1. Ensuring no other blocks are in the signal path helps to minimize power consumption and latency. The input pin at PIN12 is set to low-voltage digital input (LVDI) mode, which draws relatively little current even with a slow analog signal near its threshold (unlike a normal CMOS input which can have significant shoot through current). The PIN12 signal feeds into the OE pin output of PIN10, which is configured as a 3-state output. PIN10's input is wired to ground. The result is that when OE is high, the output is driven low. When OE is low, the output is disabled allowing it to be pulled high by an external pull-up resistor. Thus, we have the requisite inversion. Functionally this is equivalent to an NMOS, as shown in Figure 2. Externally PIN10 is wired to PIN12, completing the feedback loop. The frequency characteristics of the feedback loop can be controlled by the RC on the wire.
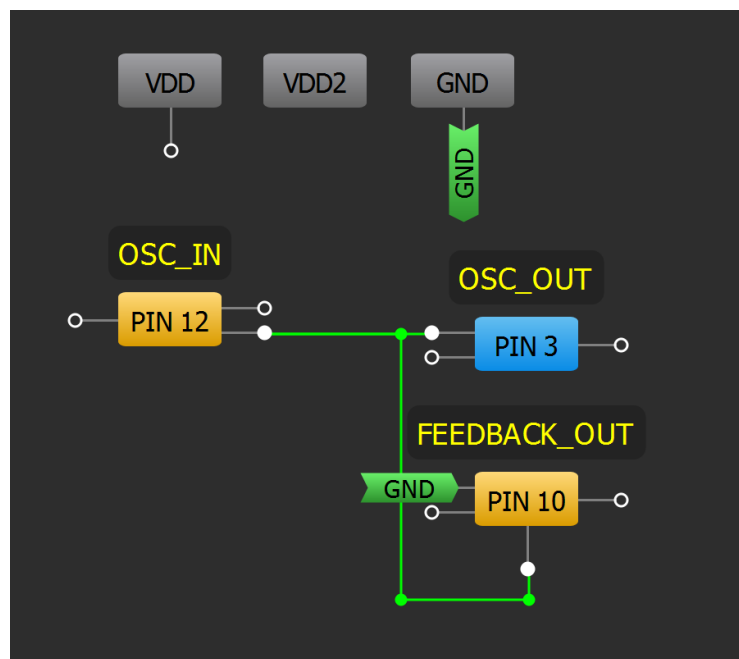


**Figure 1: View of Inverter Circuit in GreenPAK Designer**

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In this example, a separate output (PIN3) was used as a buffered test point to check the frequency without oscilloscope probes loading the feedback loop, which has a high-Z (10 MΩ) state.

PIN12 and PIN10 are powered by VDD2 (indicated by the yellow color). Externally, VDD2 is connected to VDD by a 10 MΩ resistor to limit the current. PIN10 is pulled up to VDD2 by a 10 MΩ resistor, with a 100 pF capacitor connected to ground. The cycle time can be estimated from the RC decay, i.e. time = RC * ln(VDD/(VDD-Vth)). For example, with C1*(R1+R2) giving a 2 ms time constant, the LVDI input threshold voltage (Vth) of 900 mV, and VDD at 3 V, the cycle time comes out to 713 us, or equivalently,1.4k Hz, roughly matching up with the measured results shown in Table 1.
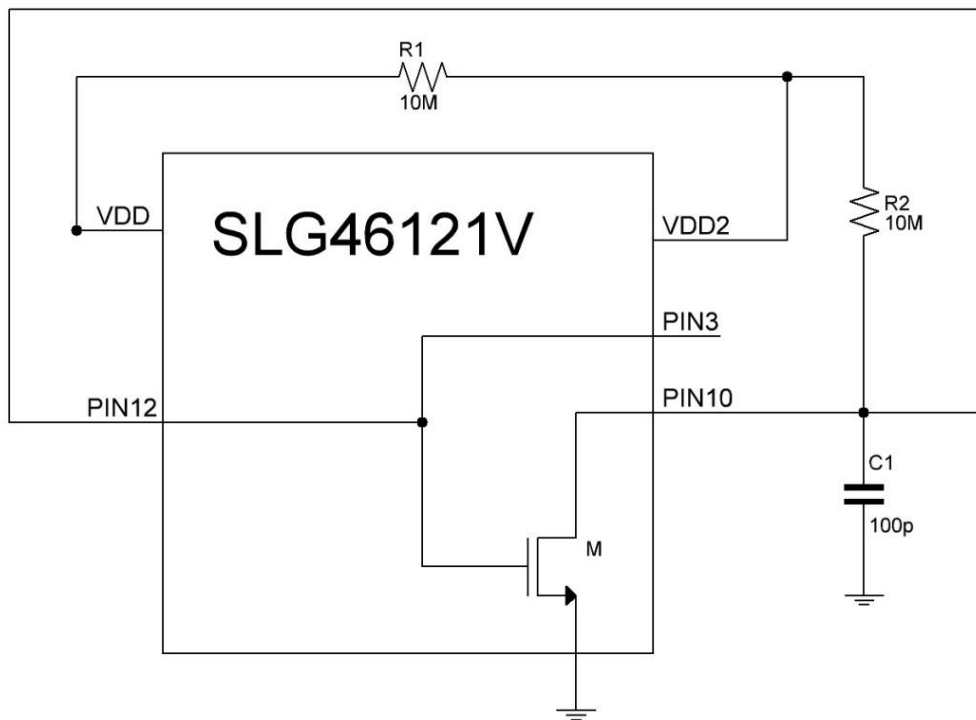


**Figure 2: Low Power Oscillator Circuit Diagram**
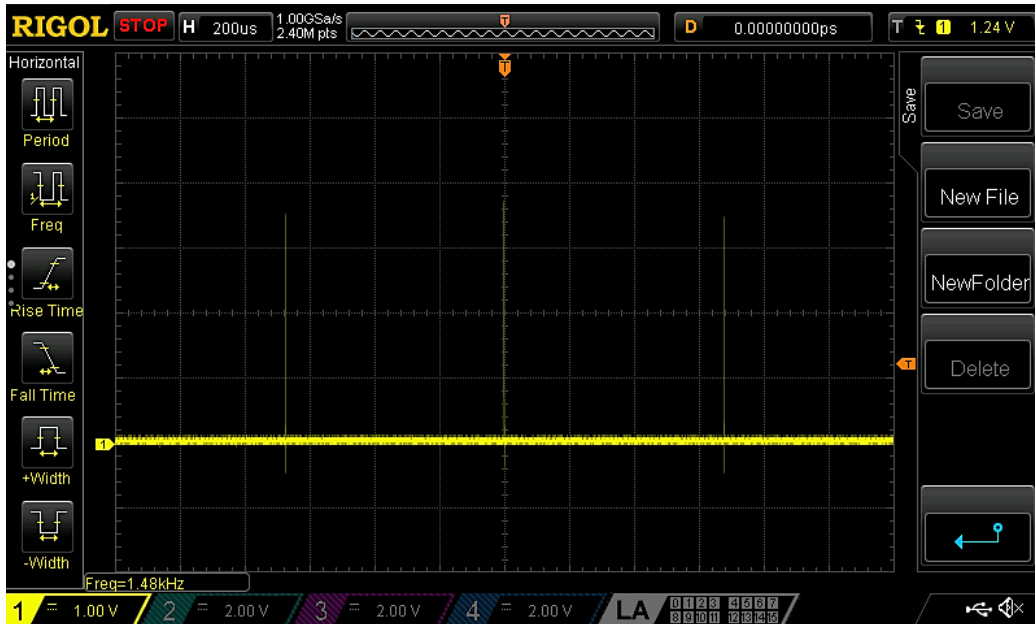
## 4.2 Results



**Figure 3: Low Power Oscillator PIN3 Output Signal with VDD at 3.3 V**



**Figure 4: PIN3 Output Signal Zoomed in to Display 80 ns Pulse Width**

Table 1 shows $I_{SUPPLY}$ and frequency measurements of the SLG46121V external RC oscillator circuit, compared to the internal oscillator of the SLG46620V. The SLG46620 low-frequency internal oscillator was chosen because it has one of the lowest power internal oscillators of the various GreenPAK chips. The supply current of the SLG46121V without the buffered output test point is also shown, since the output buffer consumes some switching power. Note the SLG46121V itself does not have a low-frequency internal oscillator that can run at a power as low as the SLG46620; its lowest power internal oscillator can run at about 5 µA, like many other GreenPAK chips. Other aspects to note are the effects of VDD on frequency and supply current. Figure 5 graphs supply current vs VDD, and Figure 6 graphs frequency vs VDD.

## External Oscillator Solutions with GreenPAK

**Table 1: Low Power Oscillator Measurements**

| VDD (V) | Isupply SLG46121 (uA) | Freq SLG46121 (kHz) | Isupply SLG46121 no external connection (uA) | Isupply SLG46620V (µA) | Freq SLG46620V (kHz) |
|---|---|---|---|---|---|
| 1.80 | 0.49 | 1.05 | 0.47 | 0.92 | 1.63 |
| 2.00 | 0.54 | 1.12 | 0.52 | 0.96 | 1.63 |
| 2.20 | 0.62 | 1.18 | 0.56 | 1.02 | 1.63 |
| 2.40 | 0.63 | 1.20 | 0.61 | 1.05 | 1.63 |
| 2.60 | 0.71 | 1.26 | 0.67 | 1.08 | 1.63 |
| 2.80 | 0.77 | 1.31 | 0.72 | 1.13 | 1.63 |
| 3.00 | 0.83 | 1.37 | 0.77 | 1.17 | 1.63 |
| 3.20 | 0.89 | 1.42 | 0.82 | 1.20 | 1.63 |
| 3.33 | 0.94 | 1.46 | 0.86 | 1.26 | 1.63 |
| 3.40 | 0.96 | 1.47 | 0.87 | 1.28 | 1.63 |
| 3.60 | 1.02 | 1.48 | 0.93 | 1.29 | 1.63 |
| 3.80 | 1.08 | 1.52 | 0.99 | 1.33 | 1.63 |
| 4.00 | 1.15 | 1.56 | 1.05 | 1.39 | 1.63 |
| 4.20 | 1.22 | 1.60 | 1.11 | 1.40 | 1.63 |
| 4.40 | 1.28 | 1.63 | 1.17 | 1.44 | 1.63 |
| 4.60 | 1.35 | 1.64 | 1.23 | 1.51 | 1.63 |
| 4.80 | 1.42 | 1.67 | 1.29 | 1.55 | 1.63 |
| 5.00 | 1.49 | 1.69 | 1.35 | 1.64 | 1.63 |
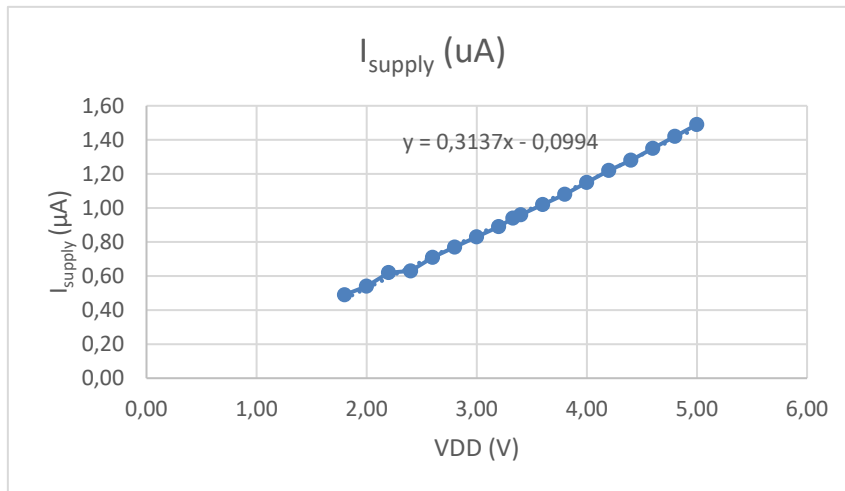
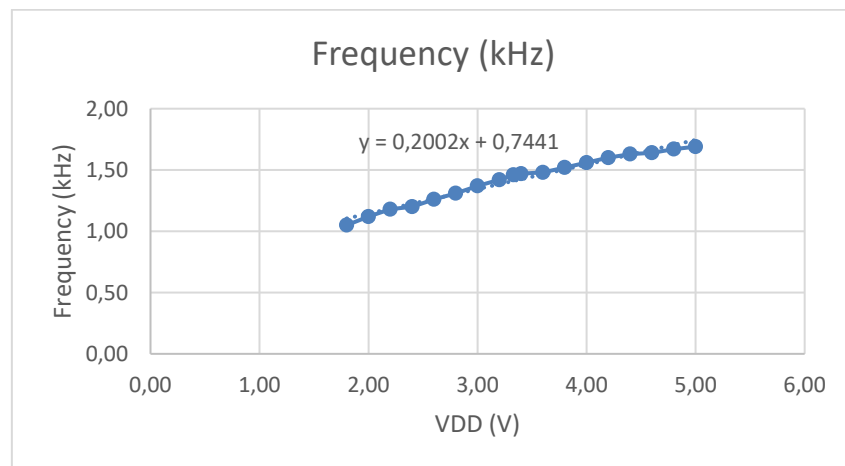**Figure 5: I_SUPPLY vs. VDD of SLG46121V Design**



**Figure 6: Frequency vs. VDD of the SLG46121V Design**

# 5    Crystal Oscillator

The same design strategy from the GreenPAK RC oscillator design can be applied to make a crystal oscillator. Some GreenPAKs have a built-in "Crystal OSC" block, consisting of a dedicated high-speed single-stage inverter which can be used with external components to create a crystal oscillator circuit. The technique we use in this application note just uses the generic inverter present in any GPIO with OE, and can be applied to any GreenPAK. For this example, we'll again use the SLG46121V chip, making use of its dual-rail feature to minimize supply current.

## 5.1    Circuit Design

Using the same basic principle as the low power oscillator discussed previously (Figure 1) the GreenPAK is configured as an inverter, but for this design the external components are arranged in the configuration of a Pierce oscillator circuit (Figure 7).

A 10 MΩ feedback resistor between PIN12 and PIN10 biases the inverter in its linear region to cause it to function as an analog amplifier. The feedback needs to have a high resistance to allow the

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resonance of the crystal to be the dominant aspect of this circuit. A 100 kΩ resistor is put in series with PIN10 to limit the current through the crystal and isolate the output driver of PIN10 from the complex impedance formed by C1, C2, and the crystal. A 32.768 kHz quartz crystal along with the two 22 pF load capacitors C1 and C2 set the resonance. PIN10 is pulled up externally to VDD2 by a 1 MΩ resistor. VDD2 is connected to VDD by a 1 MΩ resistor to limit the current. In this example, a separate output (PIN3) was used as a buffered test point to check the frequency without oscilloscope probes loading the feedback loop, which has a high-Z (10 MΩ) state.
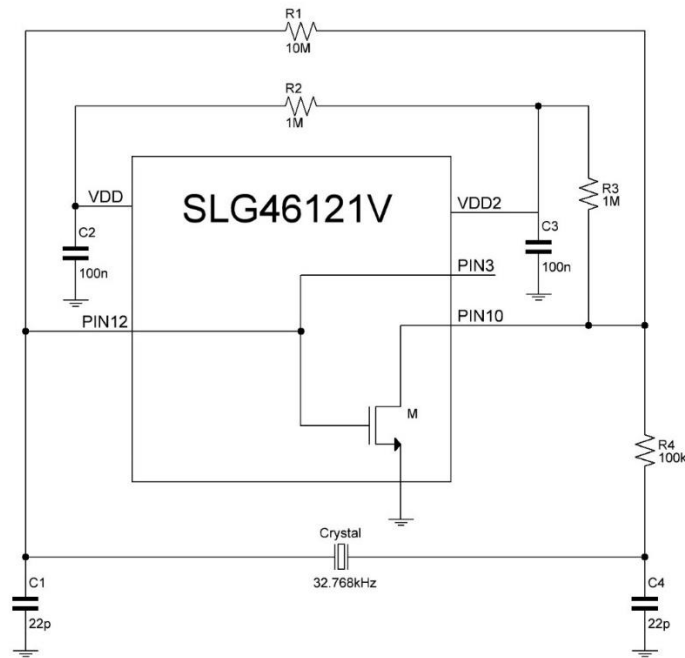


**Figure 7: Pierce Crystal Oscillator Circuit Diagram**
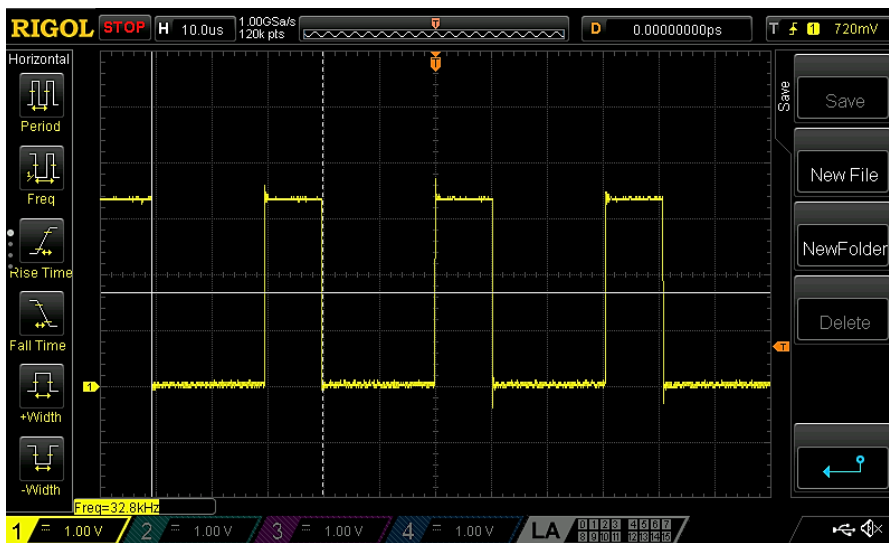
## 5.2    Results



**Figure 8: Pierce Crystal Oscillator Output with VDD at 3.3 V**

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Table 2 shows I$_{SUPPLY}$ and frequency measurements of the crystal oscillator circuit using the SLG46121V design, along with the SLG46533V using its "Crystal OSC" block for comparison. The crystal oscillator using the SLG46121V design can produce a 32.768 kHz signal consistently with much lower power consumption compared to the SLG46533V built-in crystal oscillator circuit, which is designed to run much faster clocks (≥ 5 MHz) and is not optimized for slower clocks. With the component values chosen the design only works effectively down to roughly 2.2 V, as VDD is dropped down by the 1 MΩ resistor.  Other resistor values can be chosen to tradeoff low-voltage vs low-current operation.  For ease of testing, a counter was added to the example design (Figure 10), which internally divides the frequency by 100 (327 Hz). This reduces the current draw that results from the output pin at PIN3 toggling.

**Table 2: Pierce Crystal Oscillator Measurements**

| VDD (V) | I$_{SUPPLY}$ SLG46121V with divide by 100 (µA) | Freq SLG46121V (kHz) | I$_{SUPPLY}$ SLG46533V (µA) | Freq SLG46533V (kHz) |
|---|---|---|---|---|
| 1.80 | 1.09 | 11.0 | 15.82 | 32.8 |
| 2.00 | 1.30 | 16.4 | 38.48 | 32.8 |
| 2.20 | 1.63 | 32.7 | 76.32 | 32.8 |
| 2.40 | 1.81 | 32.7 | 129.18 | 32.8 |
| 2.60 | 1.97 | 32.7 | 199.42 | 32.8 |
| 2.80 | 2.18 | 32.7 | 289.62 | 32.8 |
| 3.00 | 2.23 | 32.7 | 442 | 32.8 |
| 3.20 | 2.53 | 32.7 | 582 | 32.8 |
| 3.33 | 2.65 | 32.7 | 680 | 32.8 |
| 3.40 | 2.72 | 32.7 | 735 | 32.8 |
| 3.60 | 2.93 | 32.7 | 908 | 32.8 |
| 3.80 | 3.13 | 32.7 | 1097 | 32.8 |
| 4.00 | 3.34 | 32.7 | 1286 | 32.8 |
| 4.20 | 3.55 | 32.7 | 1495 | 32.8 |
| 4.40 | 3.78 | 32.7 | 1713 | 32.8 |
| 4.60 | 4.00 | 32.7 | 1929 | 32.8 |
| 4.80 | 4.21 | 32.7 | 2162 | 32.8 |
| 5.00 | 4.45 | 32.7 | 2401 | 32.8 |
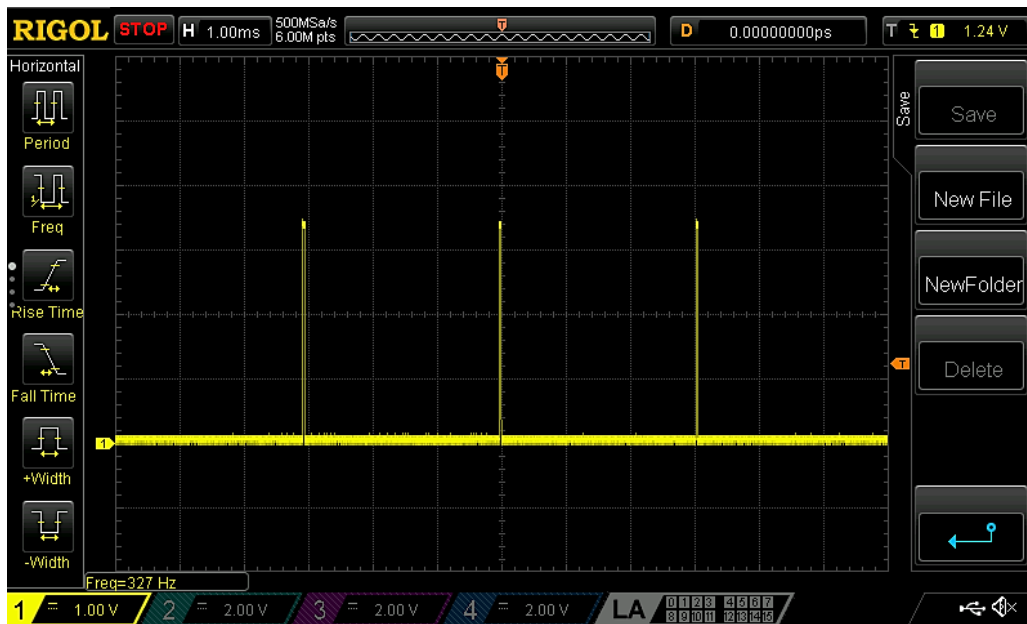
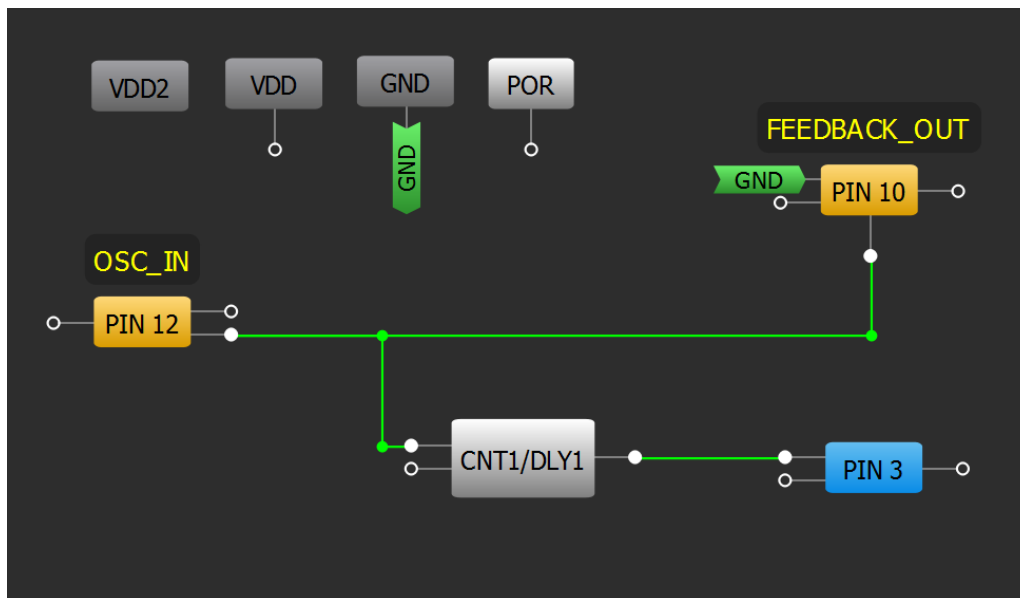**Figure 9: Pierce Oscillator Divided by 100 with a Counter**



**Figure 10: Divide by 100 test Circuit in GreenPAK Designer**

# 6    Conclusion

Two solutions were presented which implement oscillators using different external components but a similar internal GreenPAK design. The first was a sub-µA RC oscillator with a frequency that can be adjusted depending upon the external resistive and capacitive components. The second was a crystal oscillator that can be used for more precise applications.  Both solutions use minimal resources.  The designs were demonstrated on dual-rail parts to highlight their advantage in creating a low-current implementation via a current limiting path between supplies. The general technique of a pin-based inverter can also be applied in other applications as well.

## Revision History

| Revision | Date | Description |
|----------|------|-------------|
| 1.0 | 14-Mar-2018 | Initial Version |

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