

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.

External Oscillator Solutions with GreenPAK

Contents

Abstract	1
Contents	2
Figures	2
Tables	2
1 Terms and Definitions	3
2 References	3
3 Introduction	4
4 Low Power (sub-μA) RC Oscillator	4
4.1 Circuit Design	4
4.2 Results	6
5 Crystal Oscillator	8
5.1 Circuit Design	8
5.2 Results	9
6 Conclusion	11
Revision History	12

Figures

Figure 1: View of Inverter Circuit in GreenPAK Designer	4
Figure 2: Low Power Oscillator Circuit Diagram	5
Figure 3: Low Power Oscillator PIN3 Output Signal with VDD at 3.3 V	6
Figure 4: PIN3 Output Signal Zoomed in to Display 80 ns Pulse Width	6
Figure 5: I_{SUPPLY} vs. VDD of SLG46121V Design	8
Figure 6: Frequency vs. VDD of the SLG46121V Design	8
Figure 7: Pierce Crystal Oscillator Circuit Diagram	9
Figure 8: Pierce Crystal Oscillator Output with VDD at 3.3 V	9
Figure 9: Pierce Oscillator Divided by 100 with a Counter	11
Figure 10: Divide by 100 test Circuit in GreenPAK Designer	11

Tables

Table 1: Low Power Oscillator Measurements	7
Table 2: Pierce Crystal Oscillator Measurements	10

External Oscillator Solutions with GreenPAK

1 Terms and Definitions

CMIC	Configurable mixed-signal 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:

<https://www.dialog-semiconductor.com/configurable-mixed-signal>.

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. Dialog Semiconductor provides a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the Dialog IC.

- [1] [GreenPAK Designer Software](#), Software Download and User Guide, Dialog Semiconductor
- [2] [AN-CM-233 External Oscillator Solutions with GreenPAK.gp](#), [GreenPAK Design File](#), Dialog Semiconductor
- [3] [GreenPAK Development Tools](#), [GreenPAK Development Tools Webpage](#), Dialog Semiconductor
- [4] [GreenPAK Application Notes](#), [GreenPAK Application Notes Webpage](#), Dialog Semiconductor
- [5] SLG46121, Datasheet, Dialog Semiconductor
- [6] SLG46620, Datasheet, Dialog Semiconductor
- [7] SLG46533, Datasheet, Dialog Semiconductor
- [8] Ramon Cerda, *Pierce-Gate Crystal Oscillator*, Microwave Product Digest, 2008

External Oscillator Solutions with GreenPAK

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- μ A) 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- μ A 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.

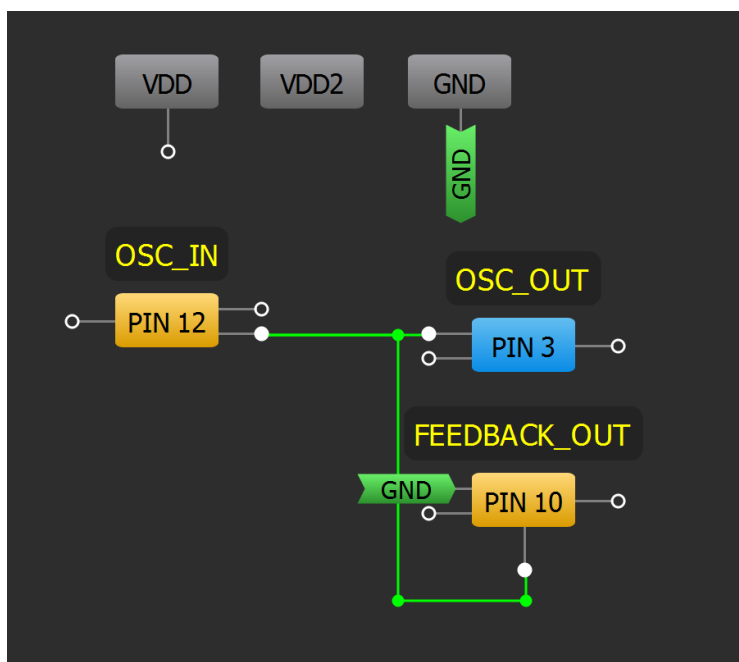


Figure 1: View of Inverter Circuit in GreenPAK Designer

External Oscillator Solutions with GreenPAK

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. $time = RC * \ln(VDD/(VDD-V_{th}))$. For example, with $C1*(R1+R2)$ giving a 2 ms time constant, the LVDI input threshold voltage (V_{th}) 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](#).

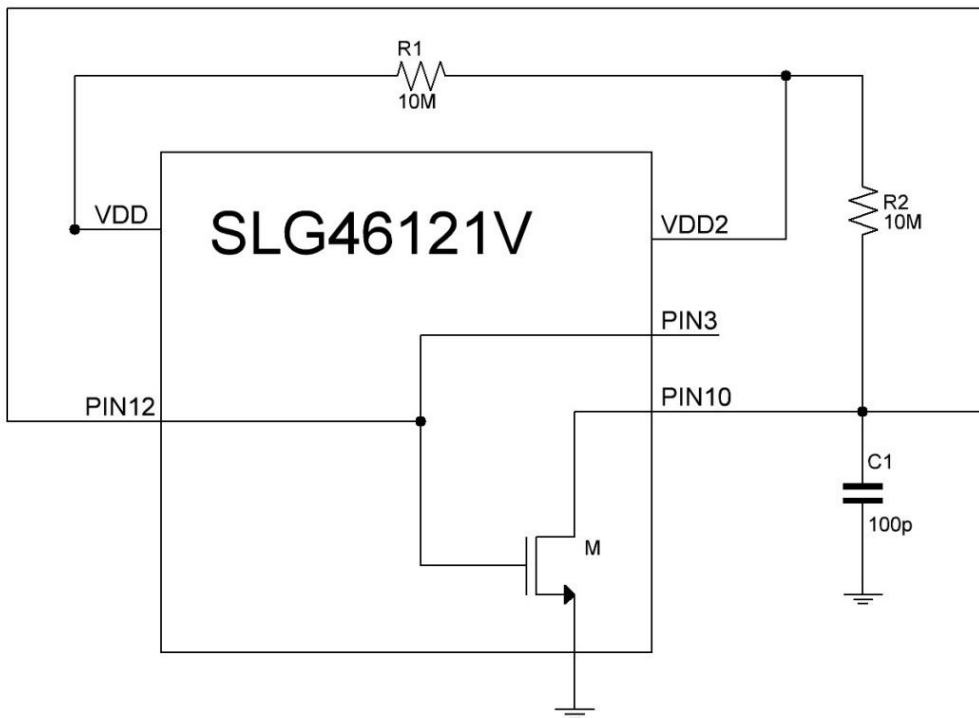


Figure 2: Low Power Oscillator Circuit Diagram

External Oscillator Solutions with GreenPAK

4.2 Results

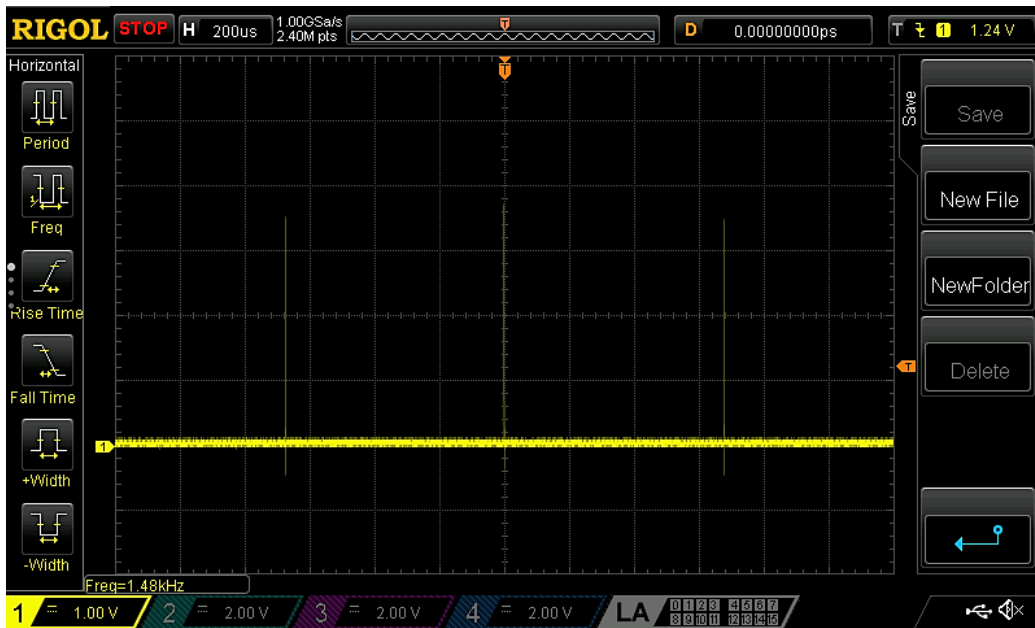


Figure 3: Low Power Oscillator PIN3 Output Signal with VDD at 3.3 V



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

External Oscillator Solutions with GreenPAK

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.

Table 1: Low Power Oscillator Measurements

VDD (V)	I _{supply} SLG46121 (uA)	Freq SLG46121 (kHz)	I _{supply} SLG46121 no external connection (uA)	I _{supply} SLG46620V (uA)	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

External Oscillator Solutions with GreenPAK

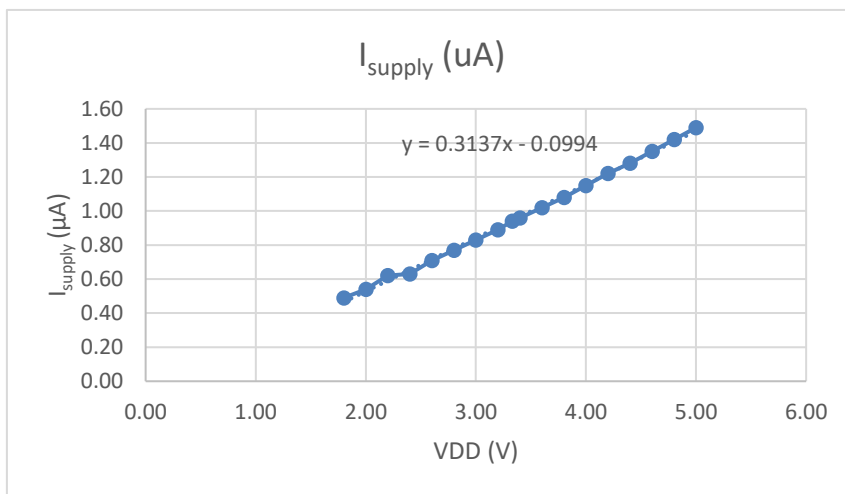


Figure 5: I_{SUPPLY} vs. VDD of SLG46121V Design

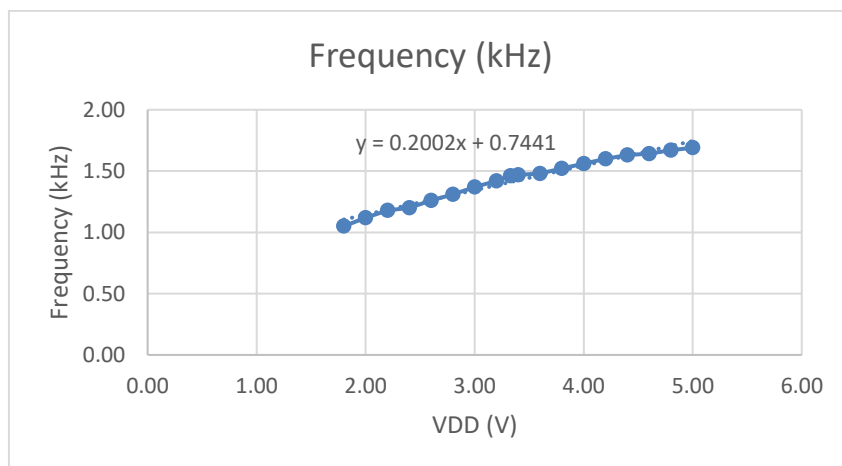


Figure 6: Frequency vs. VDD of the SLG46121V Design

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

External Oscillator Solutions with GreenPAK

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.

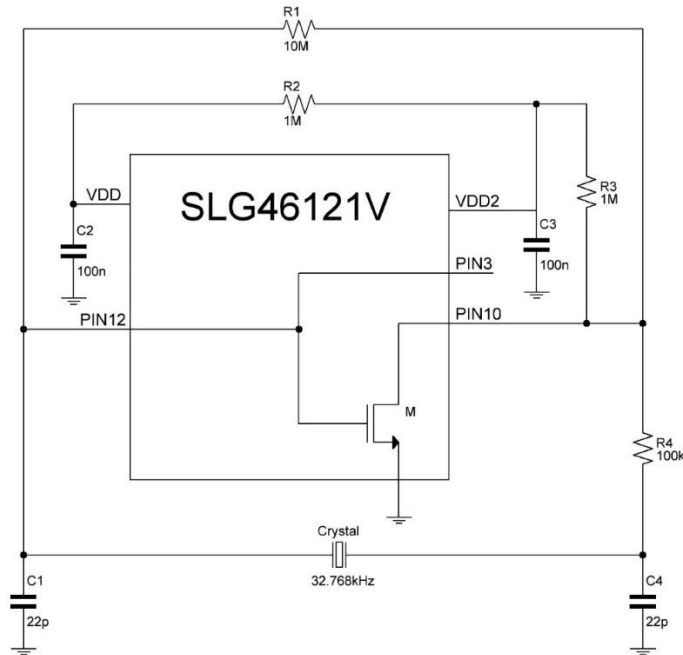


Figure 7: Pierce Crystal Oscillator Circuit Diagram

5.2 Results

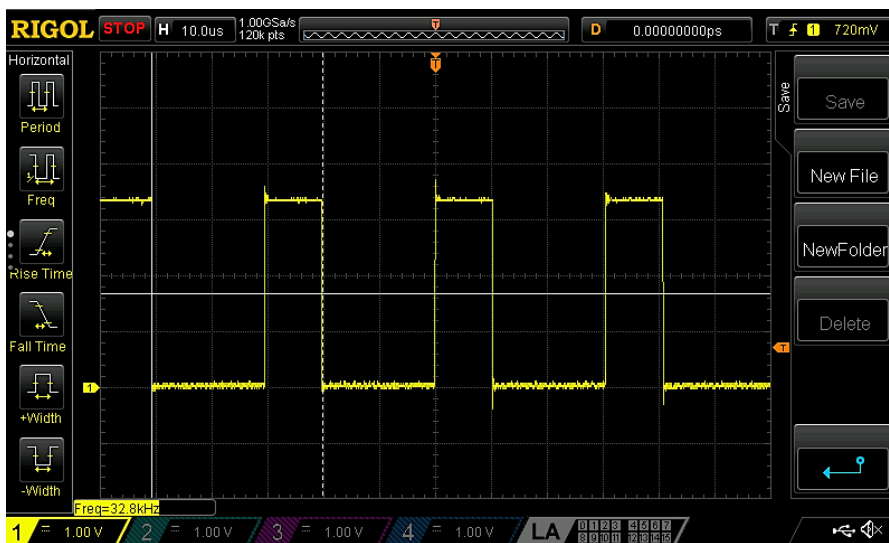


Figure 8: Pierce Crystal Oscillator Output with VDD at 3.3 V

External Oscillator Solutions with GreenPAK

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 M Ω 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 (μ A)	Freq SLG46121V (kHz)	I_{SUPPLY} SLG46533V (μ A)	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

External Oscillator Solutions with GreenPAK

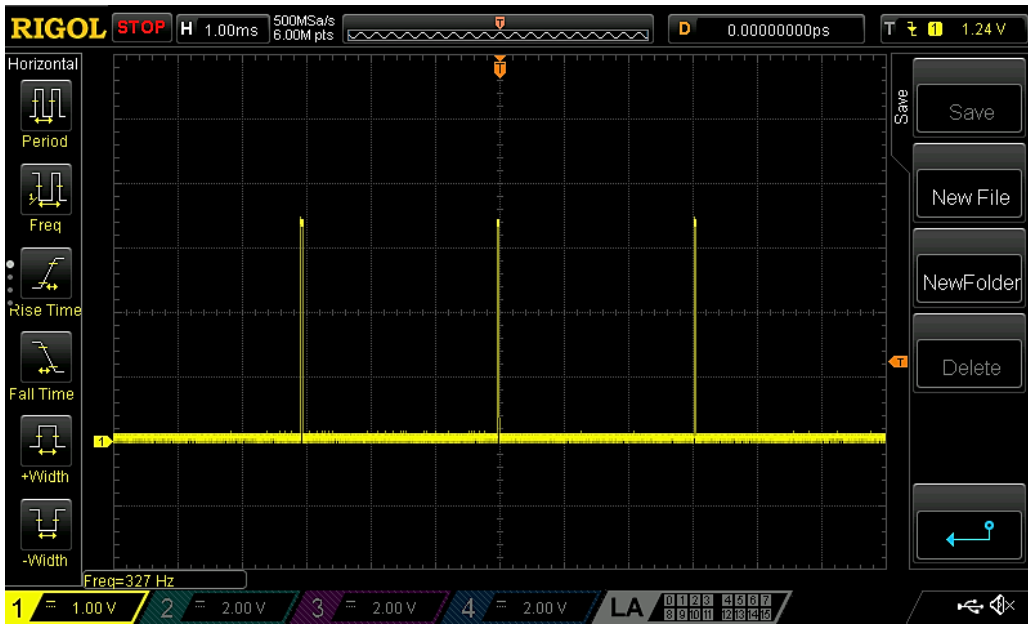


Figure 9: Pierce Oscillator Divided by 100 with a Counter

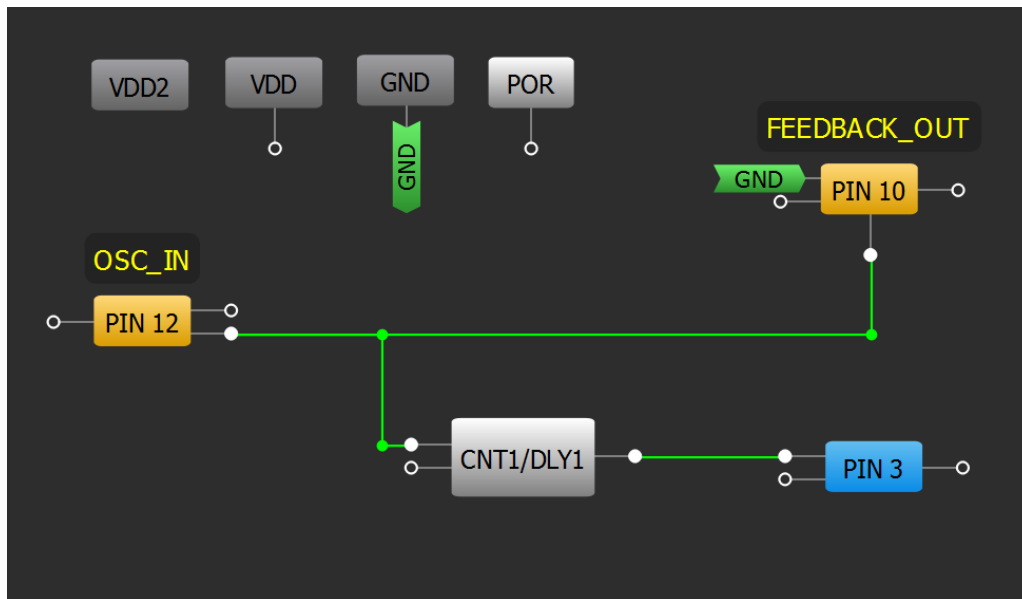


Figure 10: Divide by 100 test Circuit in GreenPAK Designer

6 Conclusion

Two solutions were presented which implement oscillators using different external components but a similar internal GreenPAK design. The first was a sub- μ A 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.

External Oscillator Solutions with GreenPAK

Revision History

Revision	Date	Description
1.0	14-Mar-2018	Initial Version

External Oscillator Solutions with GreenPAK

Status Definitions

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.

Disclaimer

Information in this document is believed to be accurate and reliable. However, Dialog Semiconductor does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information. Dialog Semiconductor furthermore takes no responsibility whatsoever for the content in this document if provided by any information source outside of Dialog Semiconductor.

Dialog Semiconductor reserves the right to change without notice the information published in this document, including without limitation the specification and the design of the related semiconductor products, software and applications.

Applications, software, and semiconductor products described in this document are for illustrative purposes only. Dialog Semiconductor makes no representation or warranty that such applications, software and semiconductor products will be suitable for the specified use without further testing or modification. Unless otherwise agreed in writing, such testing or modification is the sole responsibility of the customer and Dialog Semiconductor excludes all liability in this respect.

Customer notes that nothing in this document may be construed as a license for customer to use the Dialog Semiconductor products, software and applications referred to in this document. Such license must be separately sought by customer with Dialog Semiconductor.

All use of Dialog Semiconductor products, software and applications referred to in this document are subject to Dialog Semiconductor's [Standard Terms and Conditions of Sale](http://www.dialog-semiconductor.com), available on the company website (www.dialog-semiconductor.com) unless otherwise stated.

Dialog and the Dialog logo are trademarks of Dialog Semiconductor plc or its subsidiaries. All other product or service names are the property of their respective owners.

© 2018 Dialog Semiconductor. All rights reserved.

Contacting Dialog Semiconductor

United Kingdom (Headquarters)
Dialog Semiconductor (UK) LTD
 Phone: +44 1793 757700

Germany

Dialog Semiconductor GmbH
 Phone: +49 7021 805-0

The Netherlands

Dialog Semiconductor B.V.
 Phone: +31 73 640 8822

Email:

enquiry@diasemi.com

North America

Dialog Semiconductor Inc.
 Phone: +1 408 845 8500

Japan

Dialog Semiconductor K. K.
 Phone: +81 3 5769 5100

Taiwan

Dialog Semiconductor Taiwan
 Phone: +886 281 786 222

Web site:

www.dialog-semiconductor.com

Hong Kong

Dialog Semiconductor Hong Kong
 Phone: +852 2607 4271

Korea

Dialog Semiconductor Korea
 Phone: +82 2 3469 8200

China (Shenzhen)

Dialog Semiconductor China
 Phone: +86 755 2981 3669

China (Shanghai)

Dialog Semiconductor China
 Phone: +86 21 5424 9058