Voltage Controlled Oscillator with external RC circuit
SLG46120

This application note shows how to implement a Voltage Controlled Oscillator (VCO) using an SLG46120 GreenPAK device and a single resistor (R) with a capacitor (C) circuit. The VCO can be used to generate a fixed or variable frequency for an external circuit or even for the GreenPAK device itself. This application note comes complete with design files which can be found in the References section.

Contents

1. References

For related documents and software, please visit:

https://www.renesas.com/eu/en/products/programmable-mixed-signal-asic-ip-products/greenpak-programmable-mixed-signal-products

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. Find out more in a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the GreenPAK IC.

[1] GreenPAK Designer Software, Software Download and User Guide
[2] Voltage Controller Oscillator with external RC Circuit.gp, GreenPAK Design File
[3] GreenPAK Development Tools, GreenPAK Development Tools Webpage
[4] GreenPAK Application Notes, GreenPAK Application Notes Webpage

2. GreenPAK Circuit Design

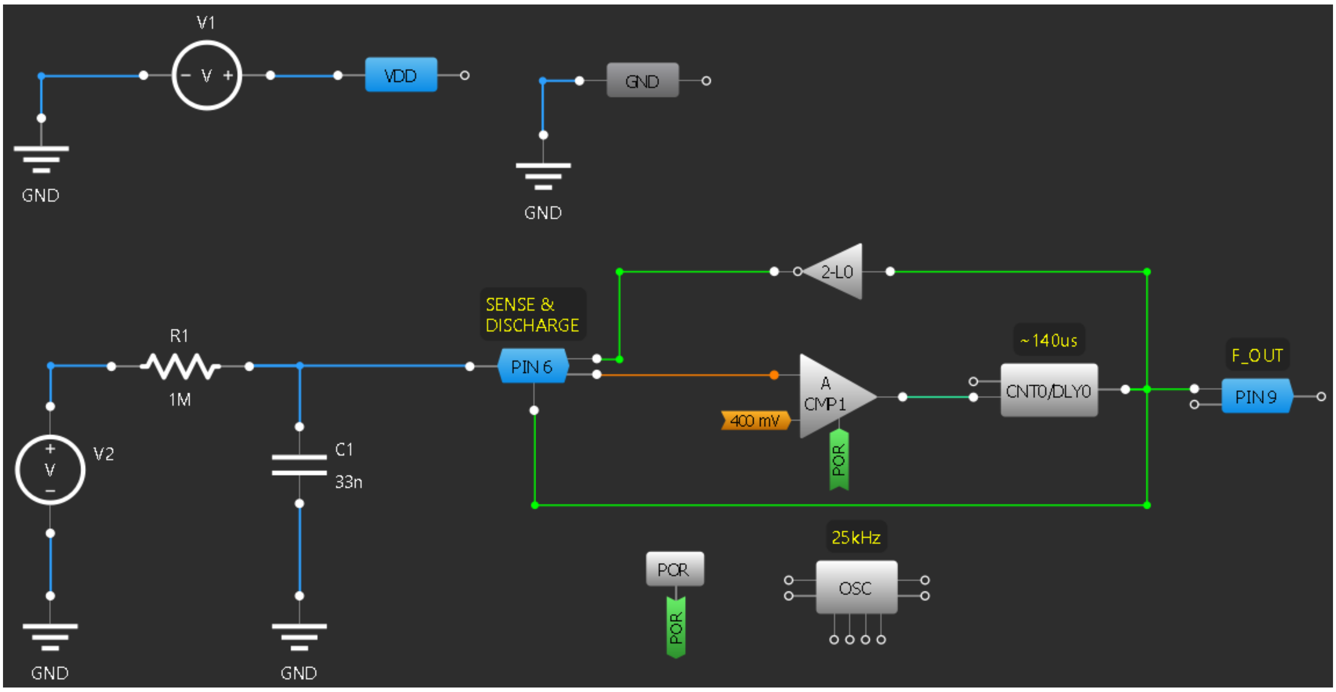

Figure 1. GreenPAK circuit design showing internal components and passive component connections

Figure 1 shows the internal SLG46120 components and the RC circuit connection to PIN 6. The external voltage used to control the circuit oscillation is represented by the voltage source V2.

The circuit operation involves slowly charging the capacitor C1 through the resistor R1, increasing the C1 voltage over time. When the voltage in C1 capacitor is above the threshold value set in the negative terminal of the internal SLG46120 analog comparator, the capacitor is quickly discharged through an open drain transistor.

The voltage in the capacitor C1 and the analog comparator output are illustrated in Figure 2.

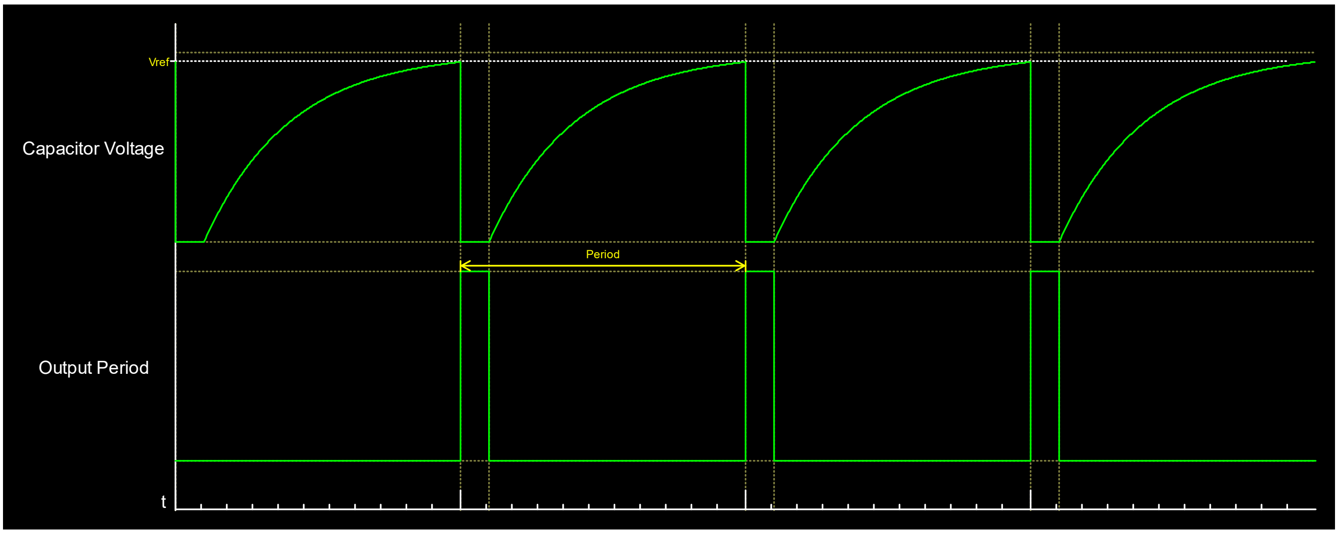

Figure 2. Voltage controlled oscillator circuit operation waveforms

The capacitor voltage in the RC circuit when it is charging the capacitor is given by equation 1.

$$V_c(t) = V_s\left(1 - e^{-\frac{t}{RC}}\right) \qquad - \textit{ equation } 1$$

Where V_c is the capacitor voltage, C is the capacitor capacitance, R is the resistor resistance, V_s is the voltage supplied to the RC circuit and t is the time instant.

Rearranging equation 1 to express the time to charge the capacitor till a reference voltage gives:

$$t_{RC} = RC \ln\left(\frac{V_S}{V_s - V_{REF}}\right) \qquad - \textit{ equation } 2$$

Where t_{RC} is the time to charge the capacitor and V_{REF} is the voltage reference.

In equation 2, the time to charge the capacitor is a function of the voltage applied to the RC circuit. Controlling the capacitor charging time allows oscillator frequency control.

The frequency of this VCO can be calculated as :

$$\textit{Frequency} = \frac{1}{t_{RC} + t_{discharge}} \qquad - \textit{ equation } 3$$

Where $t_{discharge}$ is the time to discharge the capacitor and t_{RC} is the time to charge the capacitor

As shown in Figure 1, PIN 6 is used as an analog input for the analog comparator ACMP1 and, the same pin is used as an open drain output. While the voltage in PIN 6 is below the threshold is set to 400 millivolts at negative terminal of ACMP1, the capacitor C1 charges through R1. The PIN 6 is set as an analog input because the ACMP1 output is low and the CNT0/DLY0 is low too. The output of CNT0/DLY0 is connected to the OE input of PIN 6, controlling its connection as analog input or digital output.

When the voltage is above the threshold of ACMP1 and CNT0/DLY0 outputs go to a high level then, the high-level output of CNT0/DLY0 will set PIN 6 as an open drain digital output and, the inverter will turn on the open drain output of PIN 6. The CNT0/DLY0 is configured to delay the input falling edge by 140µs, creating a short pulse of 140µs in the F_OUT output (PIN 9) and a capacitor discharge time of the same value.

The POR signal is used to turn on the ACMP1 and the internal oscillator, required for the CNT0/DLY0 delay, is configured for 25kHz.

The PIN 6, CNT0/DLY0 counter, and ACMP1 configuration are shown in Figure 3.

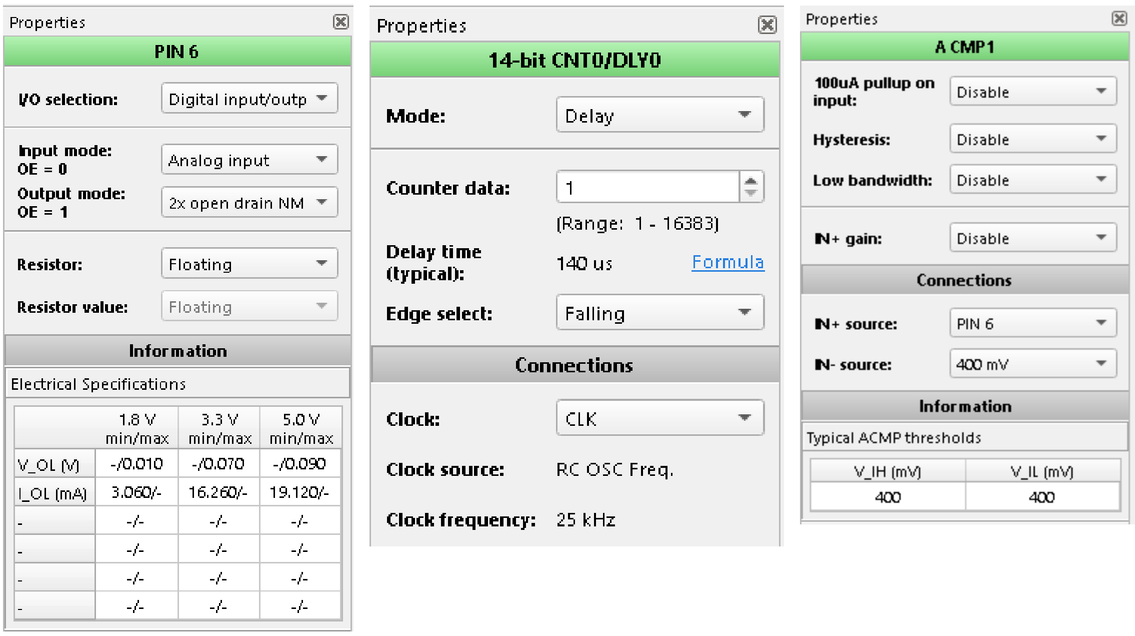

Figure 2. Configuration of PIN 6 as Analog input and Open Drain output, CNT0/DLY0 as Delay element for a falling edge, and ACMP1 configuration

3. Test Results

A prototype of this circuit was built and tested using the GreenPAK Advanced Development Platform, the SLG46120V device, and a 33nF ceramic capacitor with a 1MΩ ±5% resistor. The capacitor voltage and the frequency output were measured using the Hantek6022BL Oscilloscope.

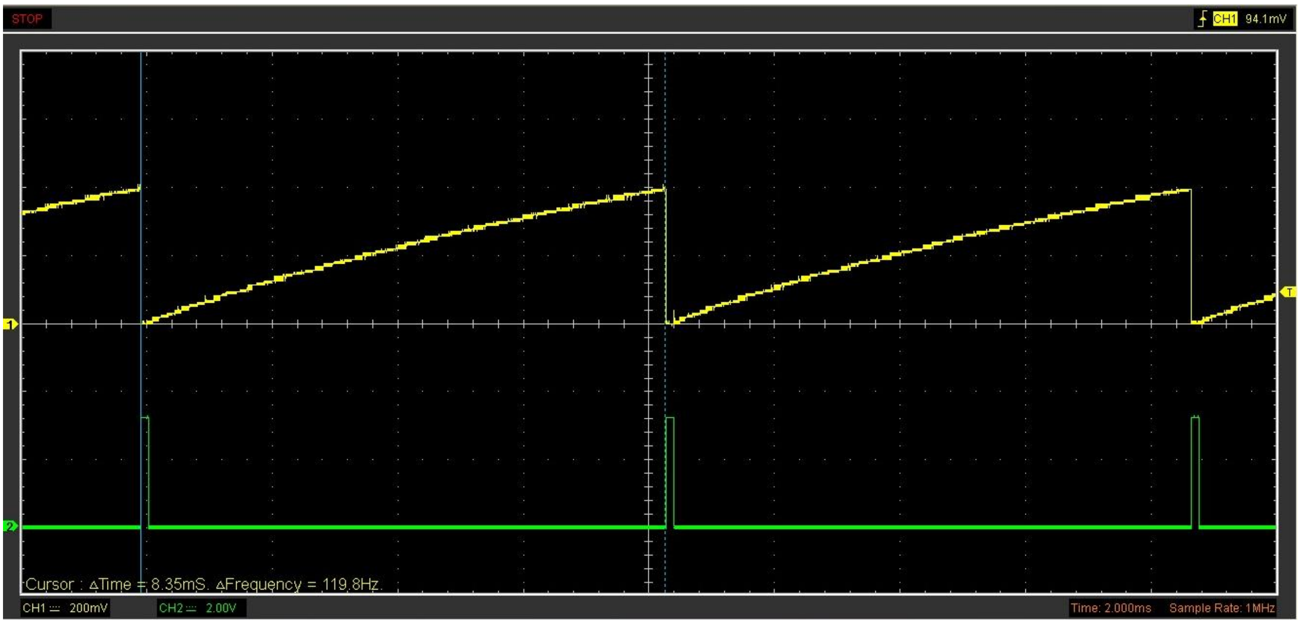

Figure 4. Measured capacitor voltage (Channel 1, in yellow) and output short pulses (Channel 2, in green) for a 1 Volt applied at the input control voltage

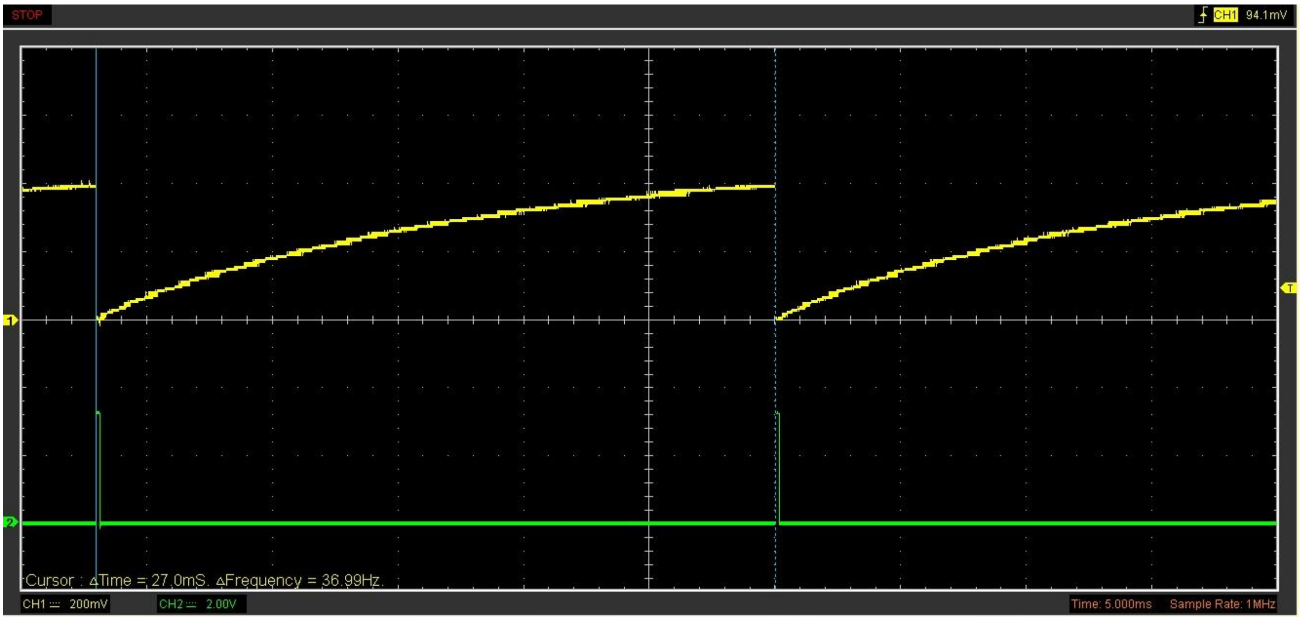

Figure 3. Measured capacitor voltage (Channel 1, in yellow) and output short pulses (Channel 2, in green) for 2 Volts applied at the input control voltage

For a DC control voltage of 1 Volt, the measured capacitor voltage and output frequency are shown in Figure 4. The measured frequency in Figure 4 is 36.99Hz.

For a DC control voltage of 2 Volts, the measured capacitor voltage and output frequency are shown in Figure 5. The measured frequency in Figure 5 is 119.8Hz.

It is possible to compare the measured curves against the simulated ones. In Figure 6 and 7 are shown the output waveforms for the respective DC control voltages of 1V and 2V.

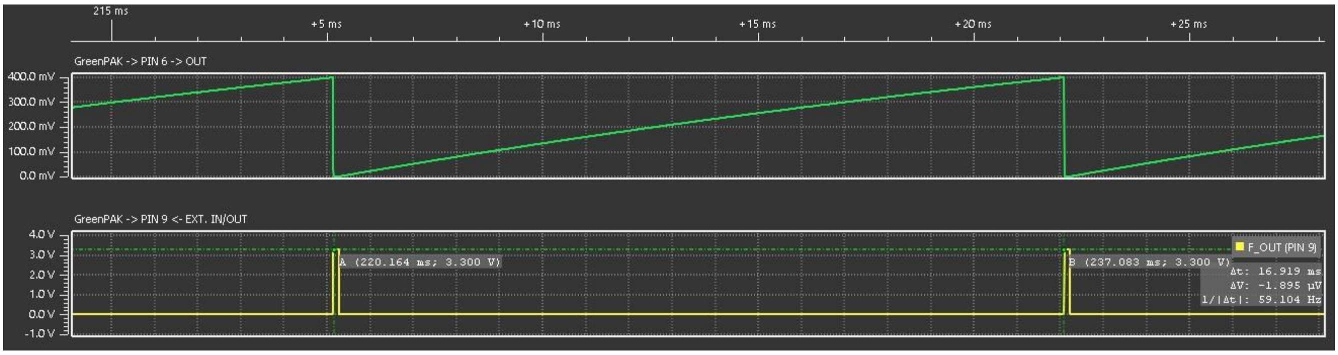

Figure 6. Simulated capacitor voltage and frequency output signal for a DC control voltage of 1V

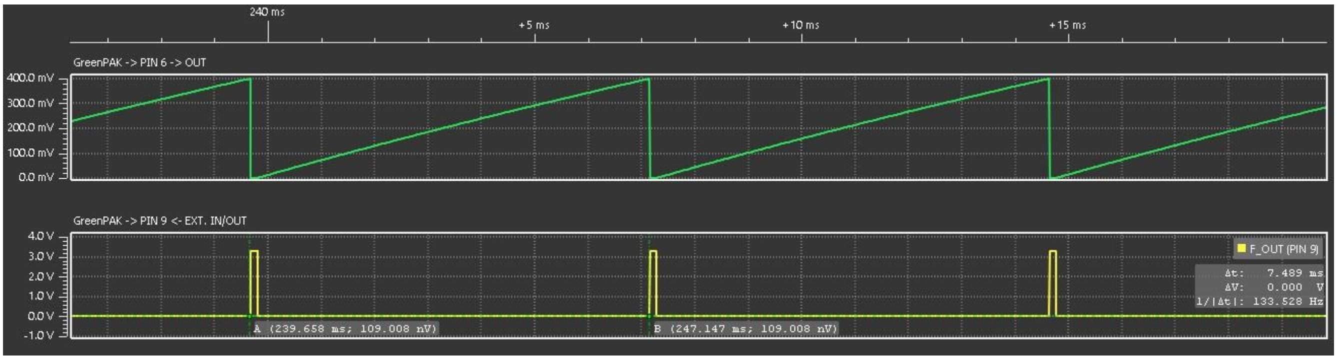

Figure 7. Simulated capacitor voltage and frequency output signal for a DC control voltage of 2V

Figure 8 shows the frequency variation as the function of the input voltage. The input voltage is trapezoidal and has a maximum value of 3 V. In Figure 8 we can see the lower frequency (lower pulse density) when the input voltage is low and, the increase in the frequency as the input voltage increases.

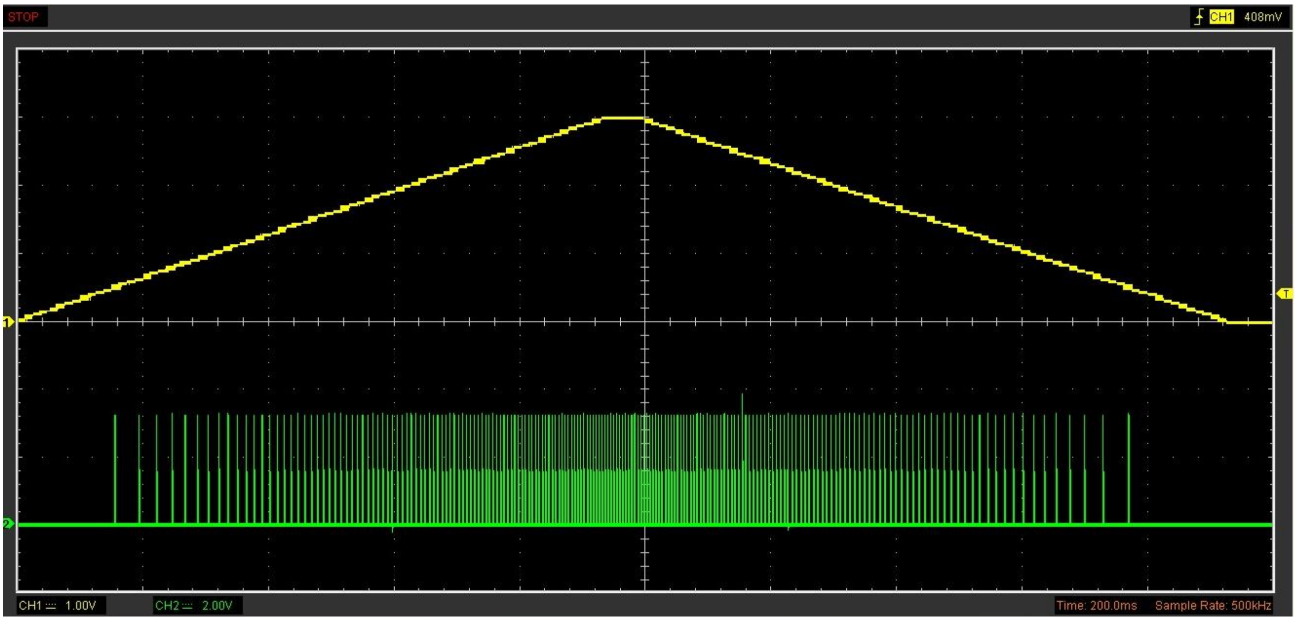

Figure 5. Output signal frequency (Channel 2 in green) in the function of the trapezoidal input voltage (Channel 1 in yellow)

4. Conclusion

The implementation of a VCO using the GreenPAK SLG46120 device and a small RC circuit was shown in this application note. This macro circuit uses a minimum number of pins and internal components from the GreenPAK device, allowing the circuit designer to implement other functionalities with the remaining device components. It is important to highlight that the frequency accuracy depends on the accuracy of the passive components. For an accurate voltage to frequency relationship, these components should have tight tolerances and, eventually, must be adjustable. Parasitic capacitances in the circuit will affect the accuracy of the voltage to frequency relationship too.

5. Revision History

Revision	Date	Description
1.00	Aug 2013	Initial Release
2.00	Sep 22, 2022	Application note review for a new device (SLG46120)

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