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The RC Charge Pump: A Versatile RF Library circuit for Phase Locked Loop's (PLL's) and Beyond

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The RC Charge Pump: A Versatile RF Library circuit for Phase Locked Loops (PLL) and Beyond.

Logic gate delays and a diode amplitude demodulator are also possible with this charge-pump

Stephen H. Kratzet, ELANIX, Inc.

Phase-Locked Loop

The RC Charge Pump token (**Figure 1**) in the RF library is a versatile token that can satisfy many design tasks. The charge pump is most often used as the loop filter in a phase locked loop (PLL). For detailed information on PLL simulation in SystemView please refer to application notes AN104 and AN105. The simplified PLL system in AN105 has been simplified even further for use as a reference system in this application note. This reference system uses an op-amp differential filter to close the loop. The resulting settling time is shown in **Figure 2**. The settling time of a 2nd PLL system is also shown (**Figure 3**). In the 2nd system, a charge pump filter is used to close the loop. The two different PLL test systems are shown in **Figure 4** and **Figure 5**. Except for the filters, the circuits are the same. Even the same parts values are used in each of the filters of the test systems as shown in **Table 1**.

In SystemView, the charge pump requires 2 source voltages (2 tokens, feeding the charge pump) to set the plus and minus charge current. By using +/- 15.0 volts and 10 K resistors, the charge current is +/-1.5 ma. This 1.5 ma value was used to get the loop to lock up in roughly the same amount of time as the op-amp circuit.

(Note: The charge pump current of one chip manufacturer has been specified as +/-5.0 ma, while another manufacturer's PLL chip may be designed and specified to provide a charge pump current as low as +/-400 ua.)

Main resistor	4.42 K
Main capacitor	2.2e-9 F
Ground resistor	1.37 K

Table 1. Loop filter component values.

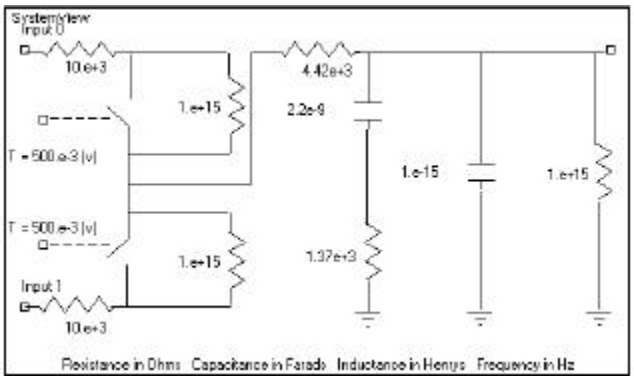

Figure 1. The RC charge pump schematic window in the RF/Analog Library.

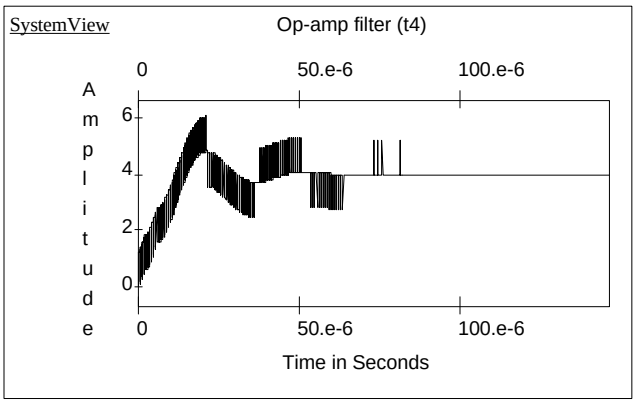

Figure 2. Settling time of the op-amp differential filter.

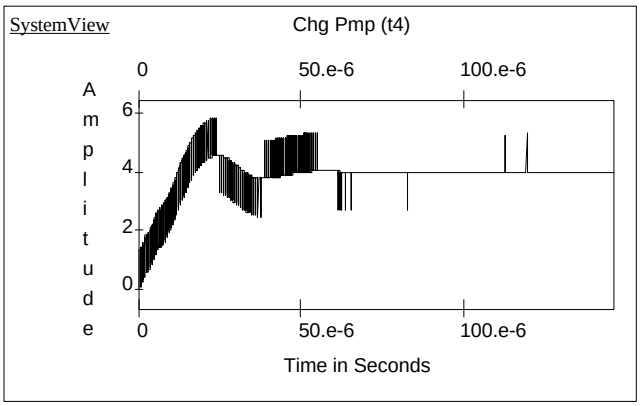

Figure 3. Settling time of the 1.5 ma charge pump filter.

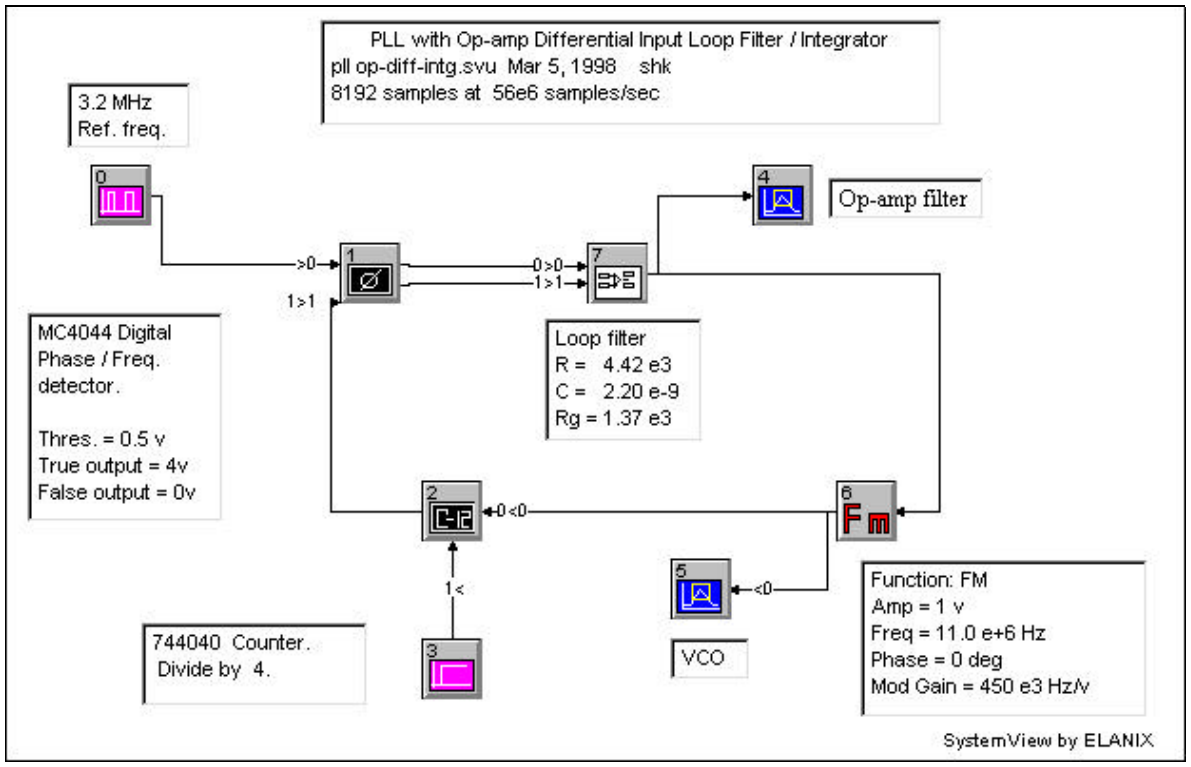

Figure 3. The Op-amp differential filter system.

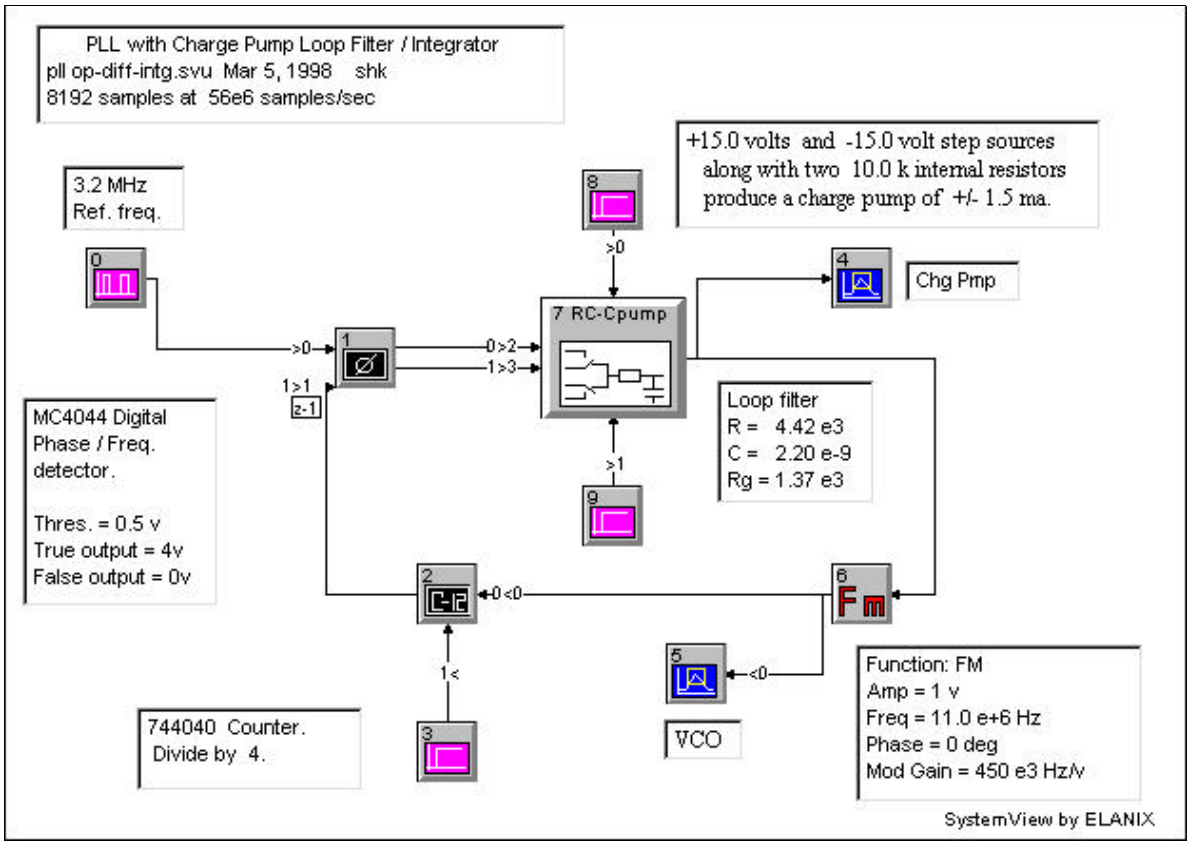

Figure 4. The charge pump filter system.

Logic Gate Delay

The charge pump token may also be used to simulate the various delays of a logic gate. **Figure 5** shows a test system that compares a normal SystemView logic buffer token with a custom buffer metasystem. In the SystemView Logic Library, the specified gate delays operate as if the gate has an internal delay line of infinite bandwidth. The gates output state changes instantly as shown in **Figure 6**. This is fine for most simulations, but sometimes it is necessary for a gate to have a more realistic rise and fall time in addition to the propagation delay (**Figure 7**). Two possible uses for a rise-and-fall time gate are: 1) A NAND gate oscillator, that has its output fed back to its input through a filter. 2) A circuit with a noisy logic signal applied to the gate to simulate logic jitter, as occurs with a noisy VCO applied to a counter (divider) in a phase-locked loop PLL.

Two RF library tokens may be used to model the rise, fall, and propagation delay of a logic gate. They are the RC-Cpump (**Figure 8**) and the RC-PLL token (**Figure 9**). The unused parts in **Figures 8** and **9** are set to very large or very small values to simplify the circuit. The complete logicdelay.mta metasystem is shown in **Figure 10**. The two sources in **Figure 10** set the HIGH and LOW output levels of the gate. The RC charge pump capacitor has been set to a value that causes the resistor values to be numerically close the rise and fall times required.

The RC-PLL filter and the threshold in the NOT gate after the filter are used together to set the gate propagation time. It may take several attempts of setting the parameters of the two tokens to achieve the desired time. The resistor in the RC-PLL filter is used to set the relative propagation delay of the gate. The one threshold parameter of the NOT gate after the RC-PLL filter eliminates the burden of fine tuning both thresholds in the RC charge pump token.. (As in the RC-Cpump token, the capacitor in the RC-PLL has been set to a value that causes the resistor value to be numerically close the desired relative propagation delay value.)

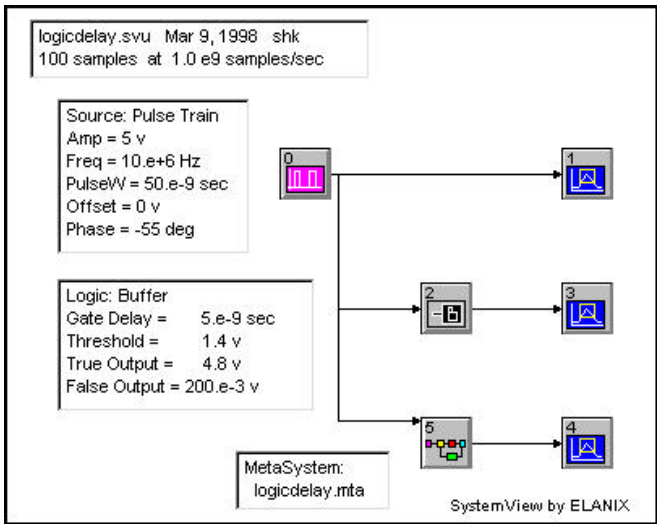

Figure 5. The response of a normal SystemView

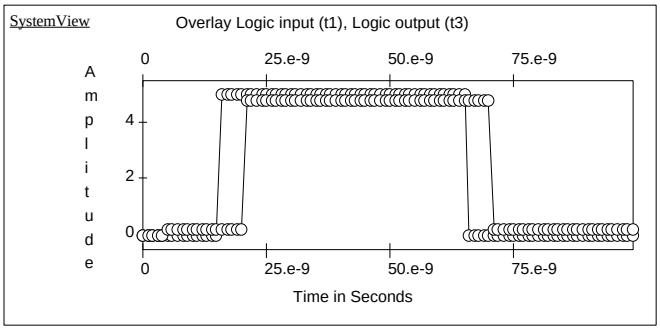

Figure 6. The response of a normal SystemView logic buffer gate.

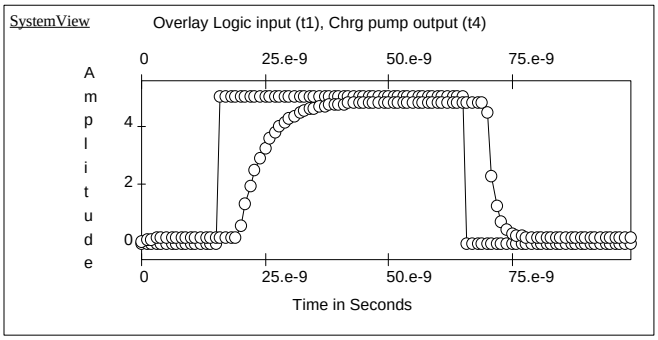

Figure 7. A custom logic buffer gate that has different rise and fall times, and a propagation delay.

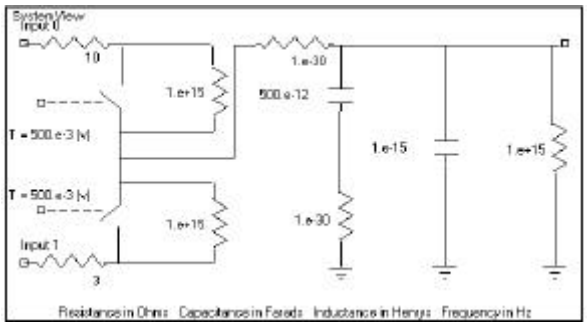

Figure 8. The RC-Cpump token schematic template.

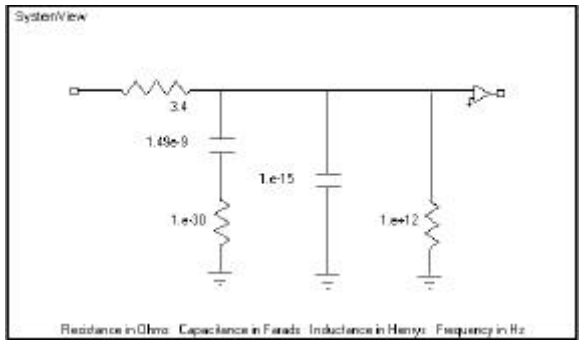

Figure 9. The RC-PLL token schematic template.

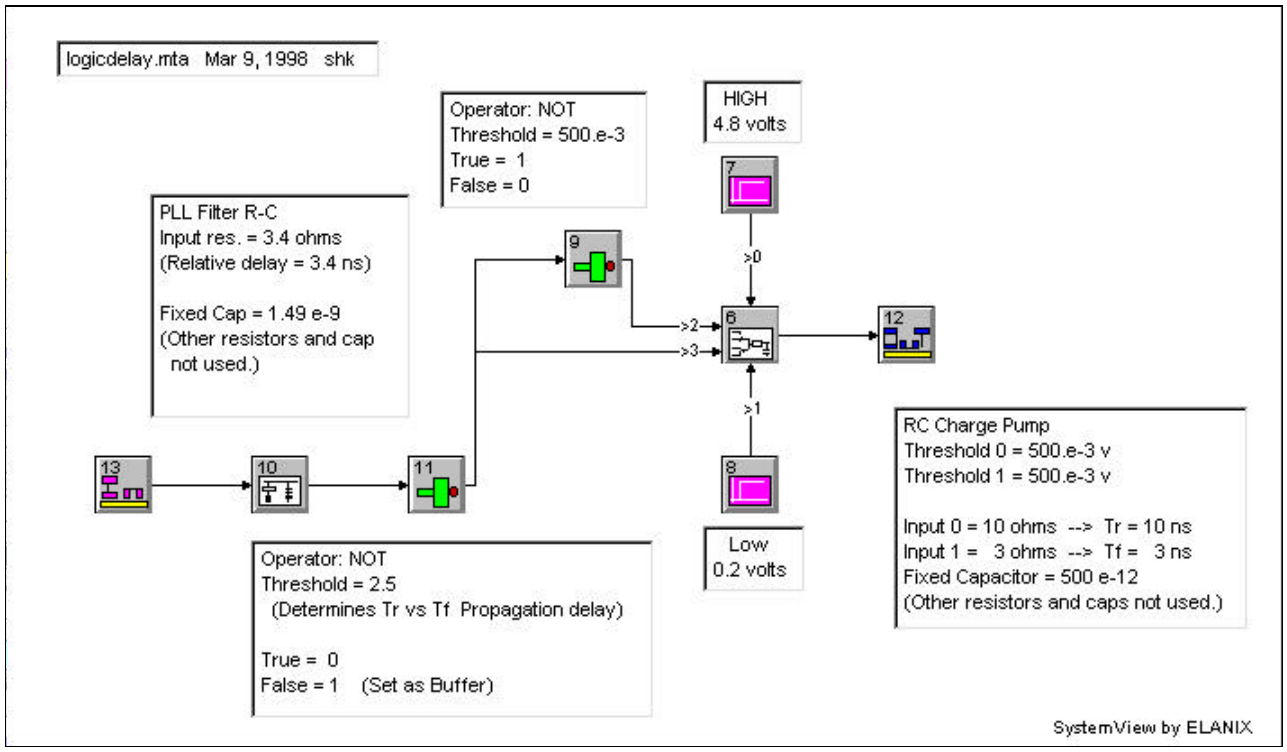

Figure 10. The complete logicdelay.mta metasystem. The two filters are detailed in **Figures 8** and **9**.

Diode Amplitude Demodulator

The output signals of SystemView tokens can be thought of as voltages from a source that has zero output impedance. This holds true even for the diode circuit tokens. This poses a problem for the designer wishing to model a simple diode detector circuit such as a diode followed by a low pass filter (**Figure 11**).

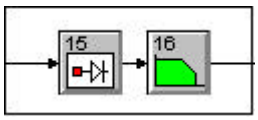

Figure 11.

In SystemView, the filter will not see the high-impedance state of the diode. With a positive voltage applied to the diode to forward bias it, the filter will see the input voltage (less the diode voltage drop). When the diode is reverse biased by applying a negative voltage to it, the filter will see a solid zero voltage, instead of an expected high-impedance. Two tokens in the RF library can come to the rescue here. Please check in your SystemView examples directory for the following file (**Figure 12**):

c:\SysVu_32\Examples\RFLib\Envp-det.svu

A simplified schematic version of this system is shown in **Figure 13**. The system in **Figure 12** simulates the high impedance state of a diode by using the RC-Charge pump token (**Figure 14**) and the Op-Hysteresis circuit token (**Figure 15**). The RC-Cpump token contains a logic level driven analog switch that can be opened or closed to control the charge applied to a RC circuit. This feature will give us the necessary high-impedance state needed for the diode detector. (Only one of the two switches in the charge pump is used here. The unused switch is disabled by applying a fixed voltage to the bottom half of the token's circuit.) The Op-Hyst token is used in its simplest configuration as a simple analog comparator. It monitors two different points of the system, the input to the charge pump, and its output. The output of the analog comparator then controls the analog switch inside the charge pump. A summary of the envelope detector operation is shown in **Table 2**. **Figure 16** shows the input to the circuit, while **Figure 17** shows the output plots. It is possible that in a future release of SystemView, several resistors and capacitors will be included as part of the diode circuit token. This will allow the high impedance state of diode detectors to be modeled within the diode token..

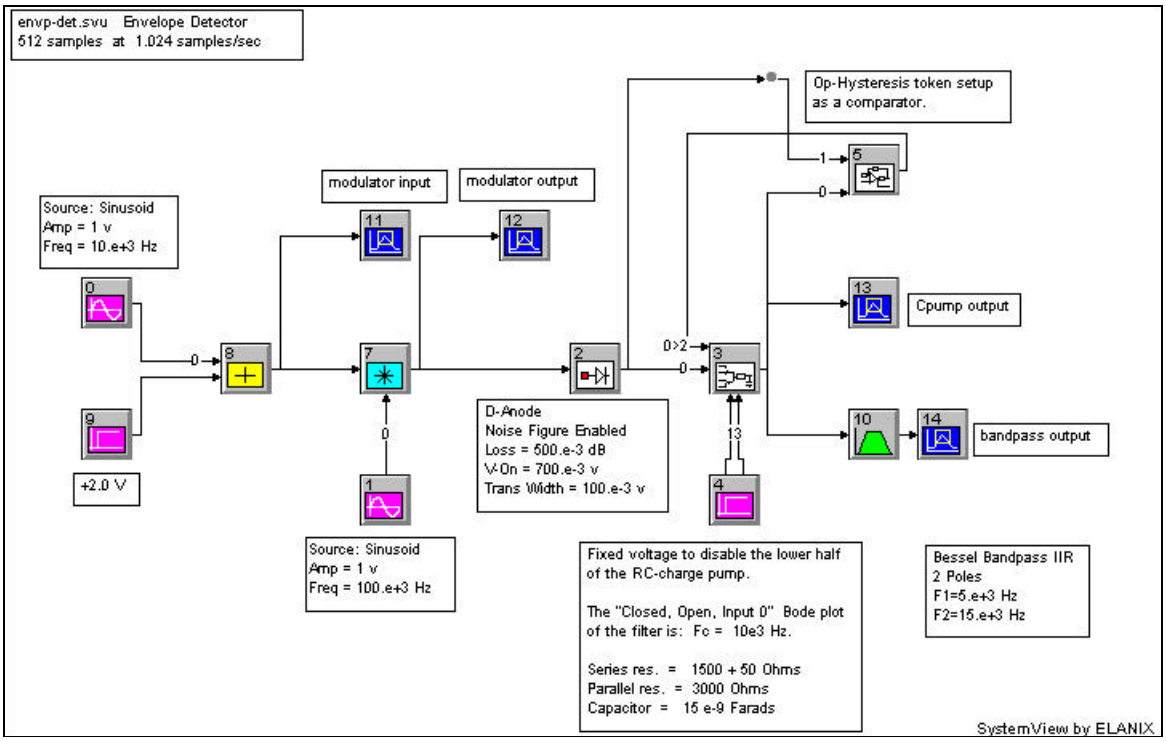

Figure 12 The SystemView example file of an envelope detector.

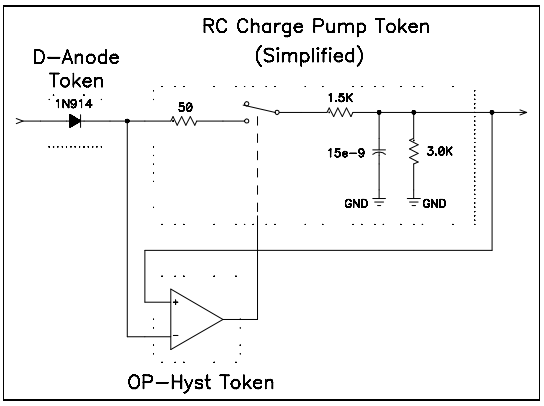

Figure 13. A simplified schematic view of the diode detector used in envp-det.svu.

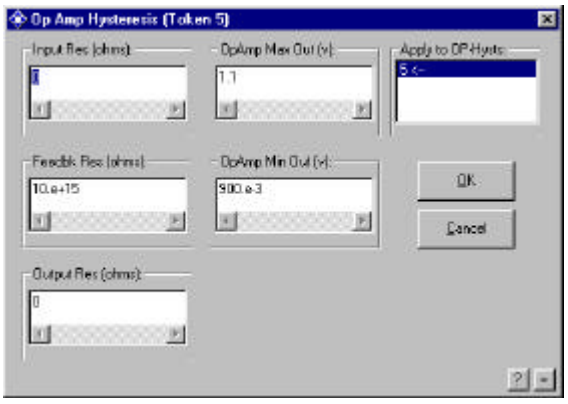

Figure 15. The OP-Hyst token parameter template.

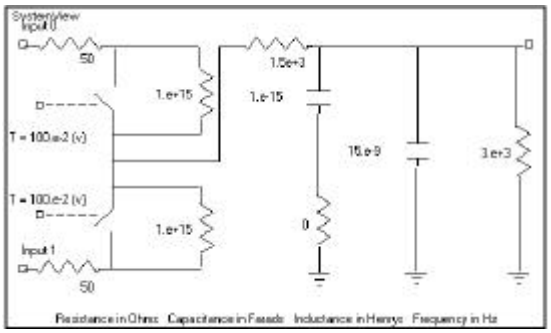

Figure 14. The RC-Cpump token schematic template.

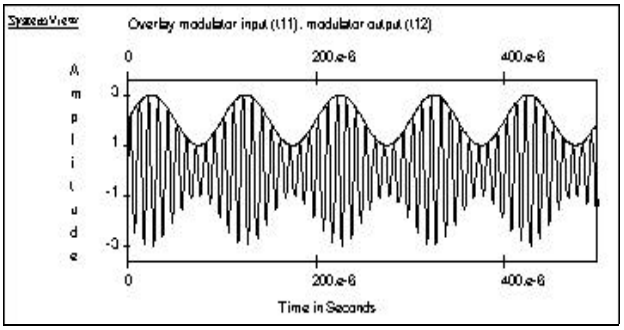

Figure 16. A sine wave signal plus a DC offset applied to the modulator produces an amplitude modulated (AM) sine wave output.

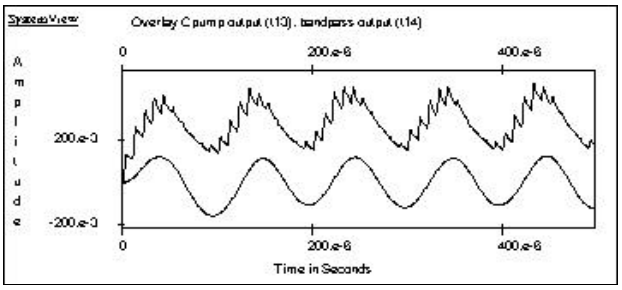

Figure 17. The Charge Pump output, before and after bandpass filtering.

Charge Pump	Op-Hyst Output	Charge Pump Switch
Input > Output	LOW	Closed
Input < Output	HIGH	Open

Table 2

More Information

For more information on SystemView simulation software please contact:

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5655 Lindero Canyon Road, Suite 721
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