

# **Configuring a Frequency to Voltage Converter**

by

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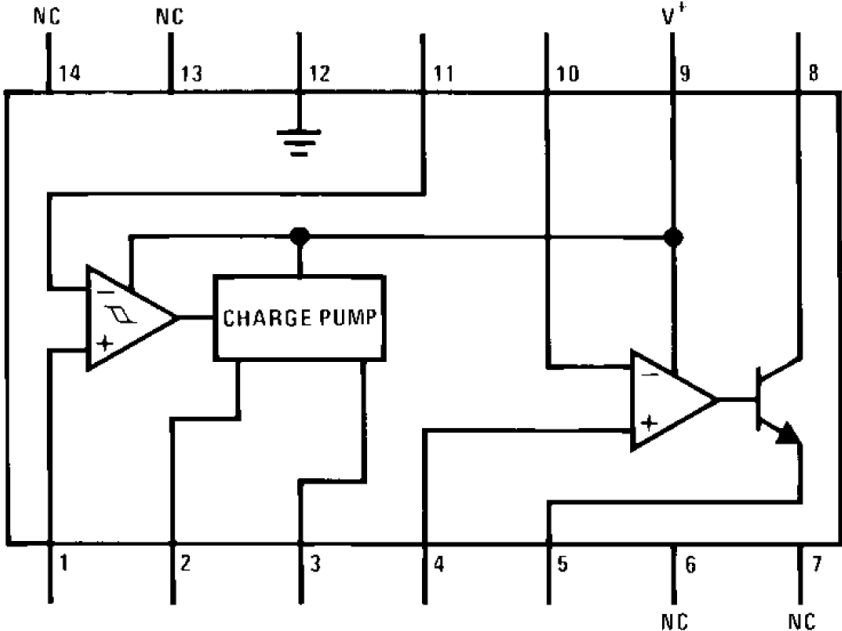
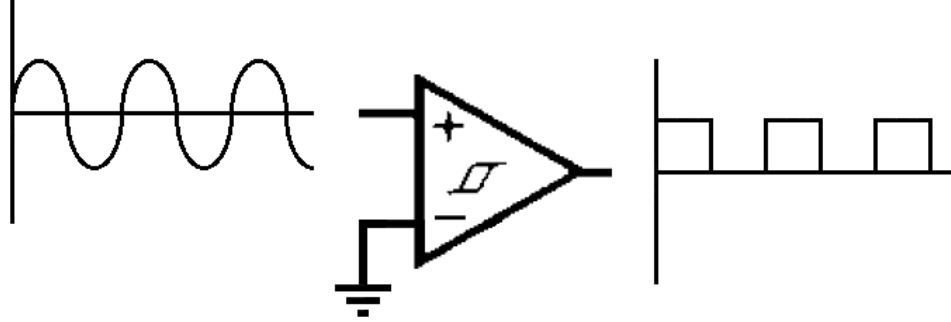


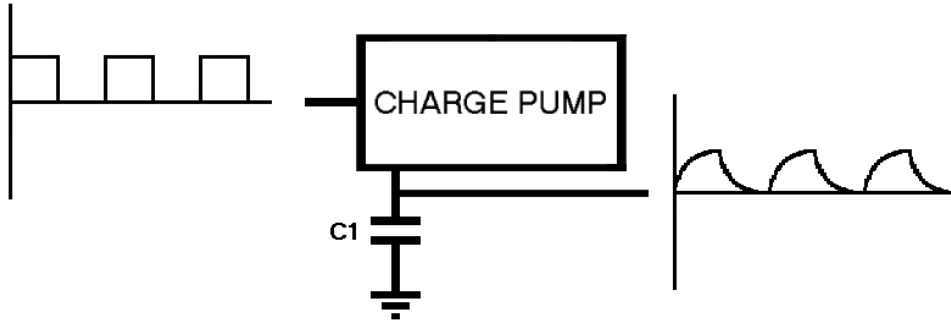
Figure 1: Circuit Layout for LM2907-N

The first part of the processing chain is the comparator. By grounding the negative differential input of the comparator we create a zero-crossing detector. Applying an AC signal with no DC offset and common grounding to the positive terminal will produce a square wave output.



*Figure 2: Output response of a zero-crossing detector*

From this square wave the charge pump uses a timing capacitor to provide the charge and discharge for the charge pumping action. The charging capacitor is attached to pin 2.



*Figure 3: Voltage response of the timing capacitor  $C_1$*

The amplitude of the resulting signal is  $V_{cc}/2$  and a change in voltage of this magnitude is experienced by the capacitor every  $1/(2f_0)$  seconds. This results in a time averaging current through the capacitor:

$$i_{avg} = C_1 \times 2f_0 \times \frac{V_{cc}}{2} = C_1 \times f_0 \times V_{cc} \quad (1)$$

This current is then mirrored on the output of the charge pump where it can be fed to a grounding resistor and filtered by a second capacitor for smoother response. The output voltage across the resistor can then be calculated using Ohm's law and Eq (1):

$$V_{out} = i_{avg} \times R_1 = C_1 \times R_1 \times f_0 \times V_{cc} \quad (2)$$

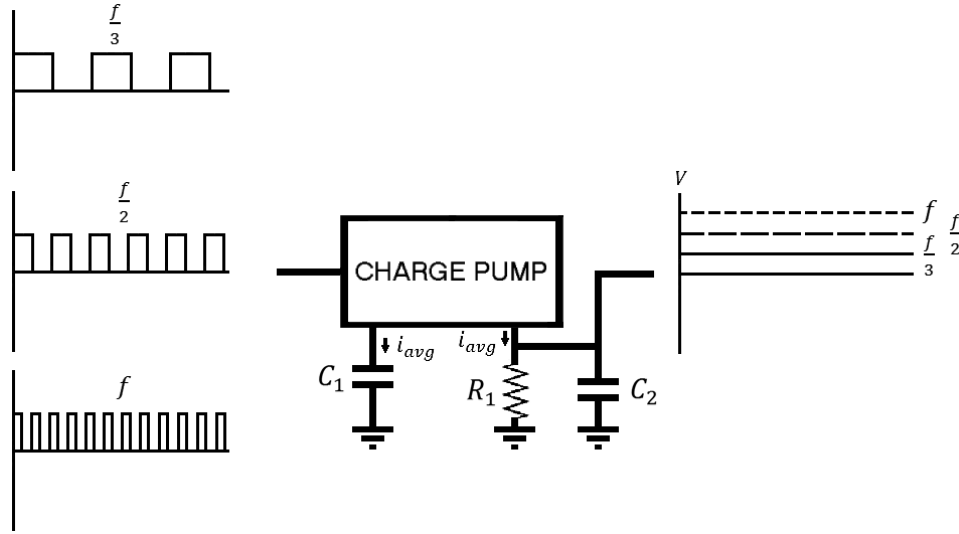


Figure 4: Expected output response of a charge pump

As we can see the output voltage is entirely affected by the frequency of the input signal in a very simple linear relationship. In our application  $V_{cc} = 5V$  and we wish to see a maximum output voltage of  $5V$  as well, therefore we are given a simple design equation relating our component values to the maximum expected frequency of our input signal.

$$C_1 \times R_1 = \frac{1}{f_{max}} \quad (3)$$

Choosing a value for  $C_2$  is relatively trivial. For low frequency signal acquisition the general rule of thumb is to increase discharge time as much as possible, this reduces response time for the frequency to voltage converter but it also stabilizes the output voltage variation.

## Example

For our project we required a frequency to voltage converter with a 450 Hz range, and output voltage of 5V. Using the assumption from before ( $V_{out} = V_{cc}$ ) we can easily find a relationship between the timing capacitor and output resistor using Eq (3).

$$R_1 = \frac{1}{f_{max} \times C_1} = \frac{1}{450 \times C_1}$$

choosing  $C_1 = 33\text{nF}$ :

$$R_1 = \frac{1}{450 \times (33 \times 10^{-9})} = 67.340 \text{ k}\Omega$$

The closest available resistor for use in our example is a  $68 \pm 5\%$  k $\Omega$  resistor. Our maximum frequency then becomes:

$$f_{max} = \frac{1}{R_1 \times C_1} = \frac{1}{(68 \times 10^3) \times (33 \times 10^{-9})} = 445.6 \text{ Hz}$$

Using Eq (2) we can also very easily calculate the linear relationship between input frequency and output voltage, with DC corresponding to 0V as a minimum limit and  $f_{max}$  corresponding to  $V_{cc}$  as a maximum limit:

$$V_{out} = \frac{V_{cc}}{f_{max}} f_{in}$$

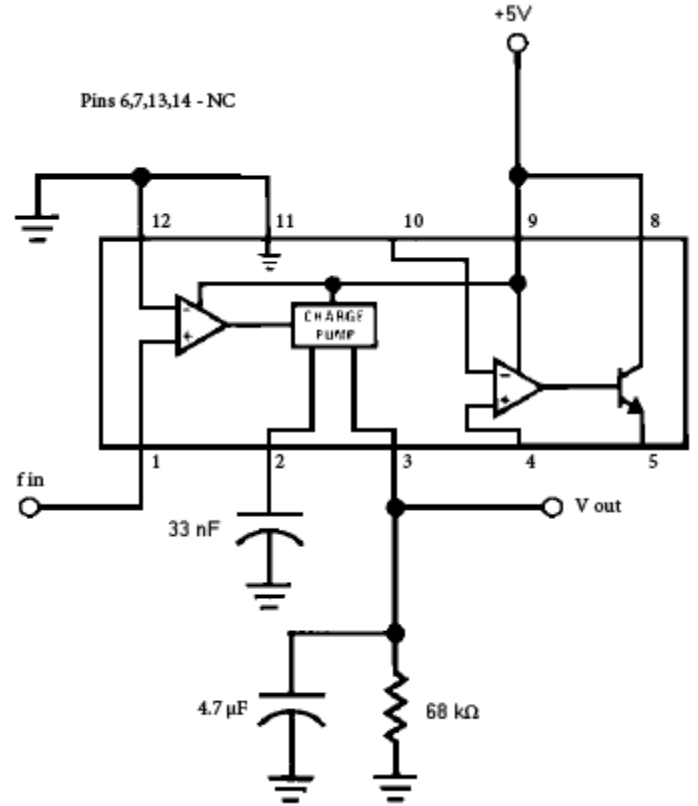
In order to compensate for any irregularities in the test circuit we choose to include calibration variables. These variables will allow us to adapt our model for use in integration with a microcontroller:

$$V_{out} = \left( \frac{V_{cc}}{f_{max}} + \Delta x \right) f_{in} + \Delta V$$

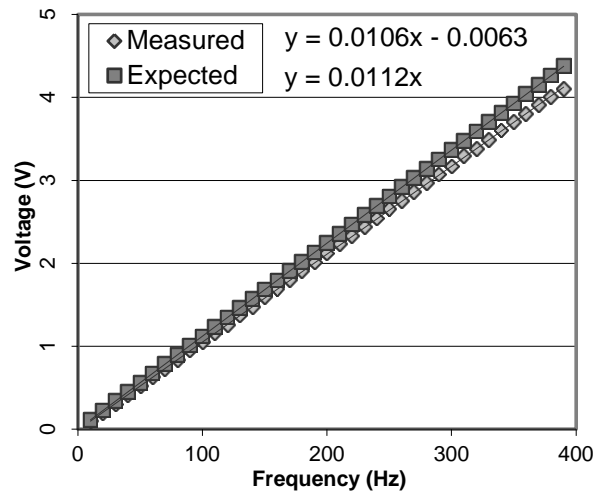
## Benchmarking

The test circuit used for the analysis of the frequency to voltage converter is shown to the right. With our compensation variables set to 0 we expected an  $f$ - $V$  relationship of  $V_{out} = \left( .01122 \frac{V}{Hz} \right) f_{in}$ .

The input signal for testing was a 1Vpp Sine wave with 0-DC and variable frequency (0 – 400 Hz). Frequencies beyond 400 Hz showed a flat response, a result we had not expected. The expected and measured voltage response is shown in *Figure 6* below. Comparison between the expected and measured functions led to determination of the calibration variables:  $\Delta x = 0.0006$  and  $\Delta V = -0.0063$



*Figure 5: Test Circuit for 450 Hz Frequency to Voltage Converter*



*Figure 6: Testing Results*

## **Resources**

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National Conductor LM2907 Datasheet (<http://www.national.com/ds/LM/LM2907.pdf>)

The Analysis and Design of Linear Circuits – 6<sup>th</sup> Edition (Thomas and Albert, 2006)

Charge Pump Circuit Design – 1<sup>st</sup> Edition (Pan, 2006)