VOLTAGE TO FREQUENCY CONVERTER BASED ON THE ANALOG DEVICES AD652 CHIP

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1. Introduction

This report shows the design and implementation of a voltage-to-frequency (VF) converter circuit based on the *Analog Devices* AD652 chip. The AD652 is an integrated circuit (IC) with a synchronous voltage-to-frequency converter (SVFC). It is a powerful building block for precision analog to digital conversion, offering typical non linearity of 0.002% (0.005% maximum) at a 100 kHz output frequency. The final stability and drift will depend on the external clock source.

This circuit can be used to measure the power at the output of a total power (continuum) detector. The DC level produced by the power detector is converted to an output frequency. This frequency will be measured later by counting pulses gated to a signal derived from the clock that feeds the AD652. The resulting system would be a high resolution A/D converter. For example, if a 4 MHz clock frequency is considered the maximum output frequency of the SVFC will be 2 MHz, and if the time gate is 4096 us, a maximum count of 8192 pulses will be measured, resulting in a 13 bit resolution converter, since $2^{13} = 8192$.

2. Description of the circuit

Figure 1 shows the AD652 connection scheme for the traditional dual supply, positive input mode of operation where the $\pm V_S$ value is ±15 V.

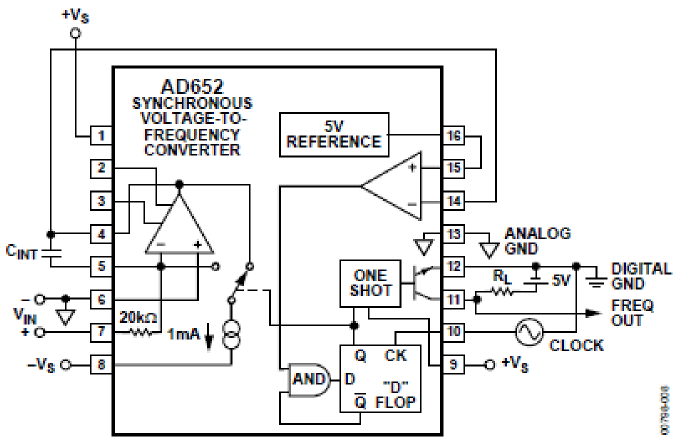

Figure 1: Standard V/f connection for positive input voltage with dual supply

The circuit shown in figure 1 has been completed with the corresponding NFE61P EMI filters and bypass capacitors in the power supply lines. In addition, a 20 KΩ variable resistor and a 250 KΩ resistor have been placed between $+V_S$ and the pins 2 and 3 of the AD652 chip in order to perform the offset calibration, as shown in figure 2.

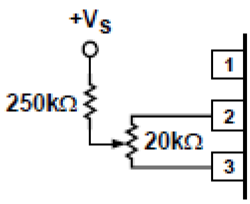

Figure 2: Scheme for offset calibration

The offset of the op amp may be trimmed to zero with the trim scheme shown in figure 2. One way of trimming the offset is by grounding Pin 7 of the device and observing the waveform at pin 4. As it will be shown later, a test point has been included on the circuit to simplify this measurement. If the offset voltage of the op amp is positive, the integrator has saturated and the voltage is at the positive rail. If the offset voltage is negative, there is a small effective input current that causes the AD652 to oscillate; a sawtooth waveform is observed at pin 4. The variable resistor should be adjusted until the downward slope of this sawtooth becomes very slow, down to a frequency of 1 Hz or less, according to the AD652 datasheet.

Figure 3 shows the block diagram of the voltage to frequency converter, with its auxiliary components for proper operation, which have been developed.

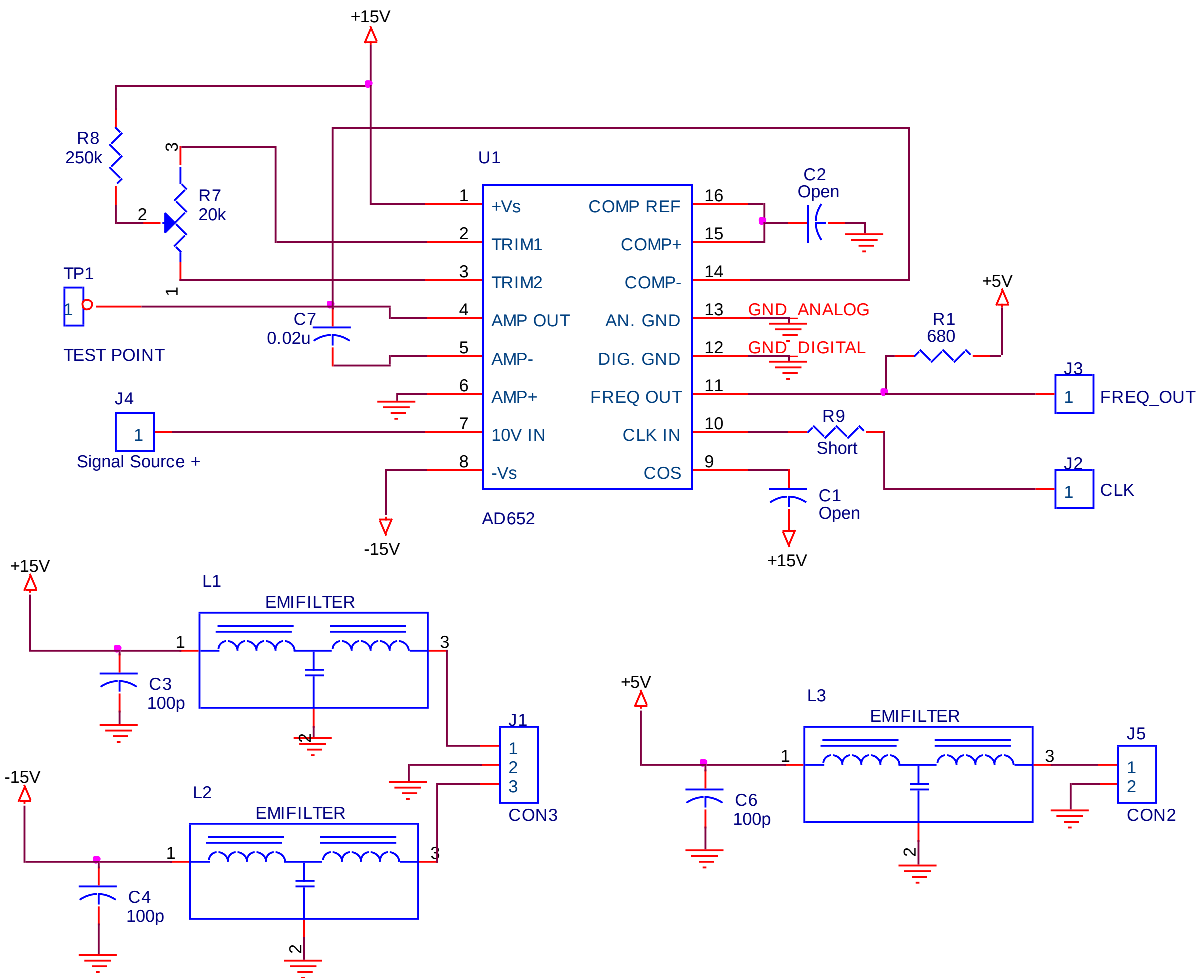

Figure 3: Schematic

3. PCB circuit design

The PCB circuit design has been routed and translated to the LPKF milling machine code with CircuitCAM 4.0. The board layout can be seen in Figure 5. The board has been manufactured in CAY's electronics laboratory and the PCB vias has been metalized in the CAY's chemical lab.

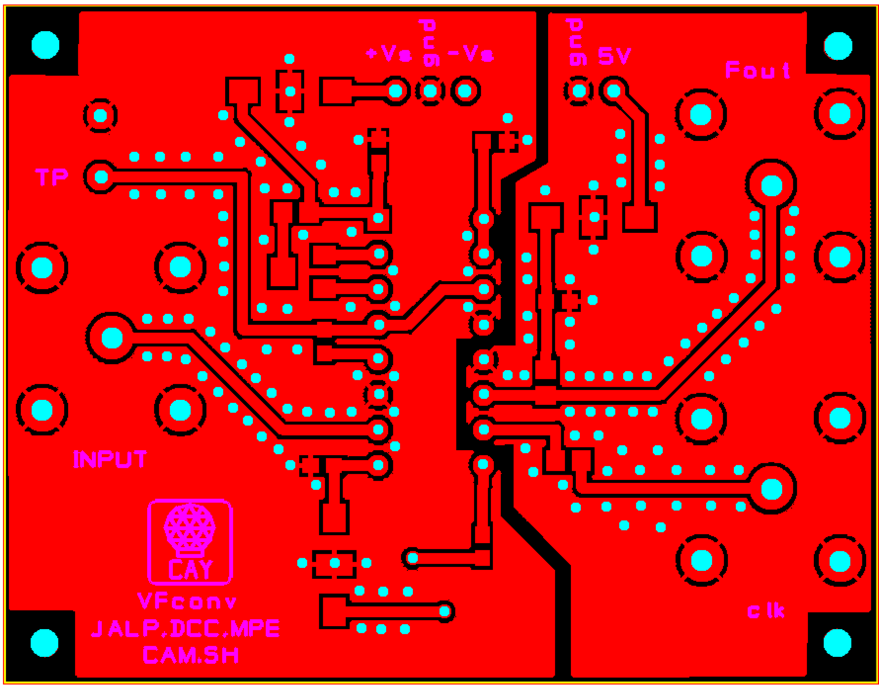

Figure 4: PCB layout (top layer)

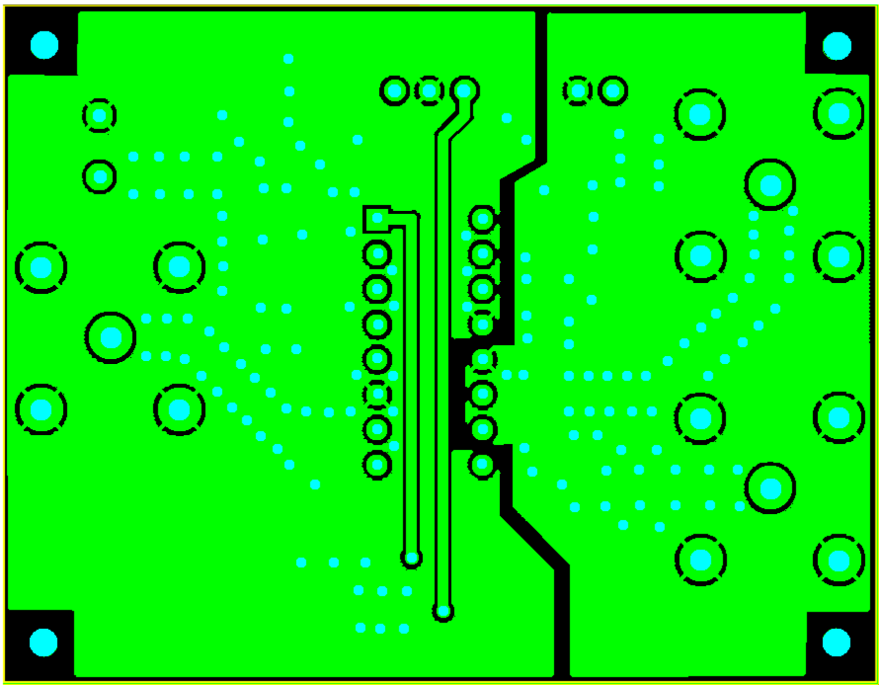

Figure 5: PCB layout (bottom layer)

Figure 6 shows the final look of the PCB circuit inside its aluminum box.

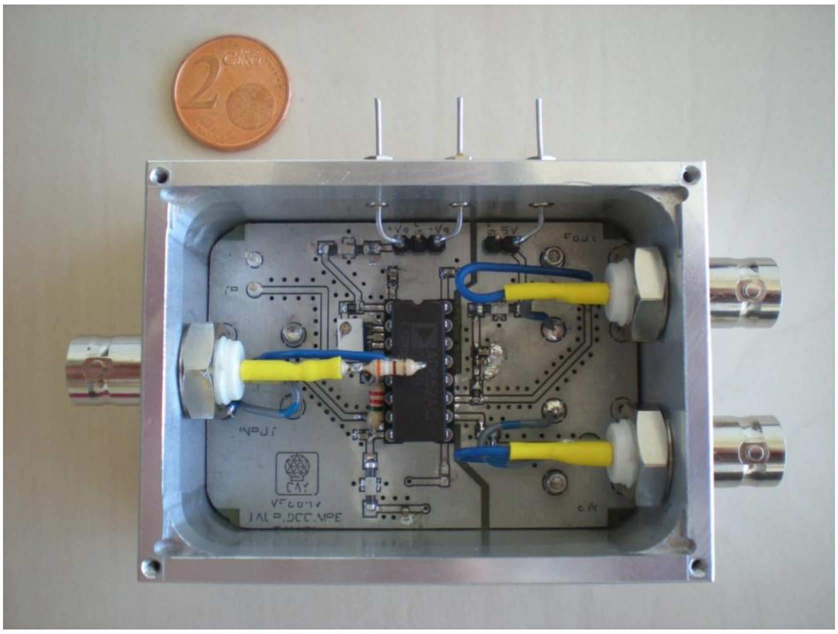

Figure 6: Printed circuit board

4. Measurements

The voltage to frequency converter has been tested for input voltage levels from 1 V to 10 V in steps of 1 V at four different clock frequencies: 50 KHz, 100 KHz, 500 KHz and 1 MHz.

The measurement of the output frequency has been carried out using the Agilent 53132A universal counter, which was configured with an integration time of 2 seconds. Then, 90 samples, approximately, were acquired for each clock and input voltage value.

The average output frequency and its typical deviation for each value of the input voltage and the clock frequency are shown in table 1 to 4.

Tables from 1 to 4 show the results for each measurement.

Fclk = 50 KHz			
	μ (Hz)	σ (Hz)	σ (%)
1 V	2.472,520380	0,021157	0,000856
2 V	4.941,371706	0,020977	0,000425
3 V	7.412,457115	0,094479	0,001275
4 V	9.882,803730	0,044762	0,000453
5 V	12.351,081666	0,159591	0,001292
6 V	14.823,538823	0,035856	0,000242
7 V	17.293,322921	0,379072	0,002192
8 V	19.762,486610	0,050228	0,000254
9 V	22.233,731276	0,331767	0,001492
10 V	24.702,682013	0,455800	0,001845

Table 1: Measurements for Fclk = 50 KHz.

Fclk = 100 KHz			
	μ (Hz)	σ (Hz)	σ (%)
1 V	4.945,312495	0,046852	0,000947
2 V	9.883,276584	0,051005	0,000516
3 V	14.824,141852	0,052019	0,000351
4 V	19.763,693212	0,054884	0,000278
5 V	24.703,864712	0,075467	0,000305
6 V	29.643,708572	0,091394	0,000308
7 V	34.583,833306	0,112618	0,000326
8 V	39.526,177079	0,089121	0,000225
9 V	44.469,949680	0,163683	0,000368
10 V	49.407,541852	0,154416	0,000313

Table 2: Measurements for Fclk = 100 KHz.

Fclk = 500 KHz			
	μ (Hz)	σ (Hz)	σ (%)
1 V	24.708,746679	0,352983	0,001429
2 V	49.410,350931	0,261193	0,000529
3 V	74.125,445273	0,260054	0,000351
4 V	98.815,652262	0,475083	0,000481
5 V	123.526,501287	0,323329	0,000262
6 V	148.218,502126	0,423951	0,000286
7 V	172.925,924456	0,649278	0,000375
8 V	197.640,685216	0,550368	0,000278
9 V	222.332,860031	0,700676	0,000315
10 V	247.028,106417	0,544355	0,000220

Table 3: Measurements for Fclk = 500 KHz.

Fclk = 1 MHz			
	μ (Hz)	σ (Hz)	σ (%)
1 V	49.447,739263	0,467180	0,000945
2 V	98.869,885053	0,683196	0,000691
3 V	148.241,944750	1,169837	0,000789
4 V	197.626,761230	0,846404	0,000428
5 V	247.048,674750	0,593806	0,000240
6 V	296.430,795448	0,857682	0,000289
7 V	345.847,956999	1,165187	0,000337
8 V	395.272,979582	1,177912	0,000298
9 V	444.647,508734	1,160502	0,000261
10 V	494.029,759933	1,522012	0,000308

Table 4: Measurements for Fclk = 1 MHz.

It can be observed that the results obtained at lower clock's frequencies have smaller typical deviation values.

Figure 7 shows the graphical representation of all these values.

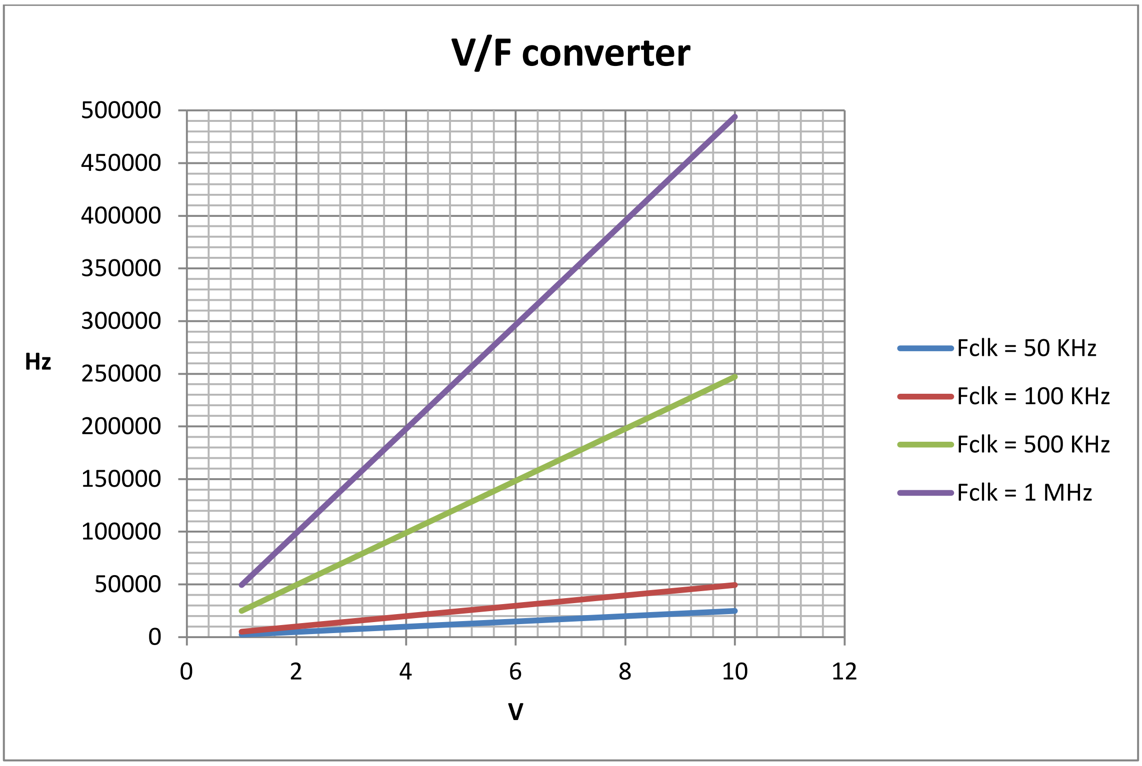

Figure 7: V/F converter graphical results

Table 5 shows the equation fitted to the data in order to obtain the transfer function of the SVFC (frequency in Hz versus input voltage in volts for each value of the clock frequency). It can be seen that the SVFC transfer function is linear.

F_{CLK} (Hz)	Equation
50 KHz	F_{OUT} (Hz) = 2470,1·V + 1,8618
100 KHz	F_{OUT} (Hz) = 4940,5·V + 2,5761
500 KHz	F_{OUT} (Hz) = 24703·V + 8,9169
1 MHz	F_{OUT} (Hz) = 49399·V + 50,319

Table 5: V/F circuit equations

5. Conclusions

A voltage to frequency converter based on the *Analog Devices* AD652 chip has been developed to obtain voltage measurements with a high resolution.

The circuit has been implemented in a printed circuit board with the LPKF milling machine placed at CAY receiver's laboratory and works with a dual supply of ±15 V and positive input voltages.

The voltage to frequency converter has been tested and completely characterized at CAY's laboratories obtaining the results shown in section 4, which conclude that its transfer function is linear.

It is recommended to work with low clock frequencies in order to increase the accuracy and the stability of the output frequency.

6. Acknowledgments

The authors wish to thank the help provided by Carlos Almendros during the laboratory tests, Sergio Henche for the assembly of the board, José Manuel Hernández for the metallization of the vias and chemical finishing of the board, Carlos Albo for providing the software to acquire the measurements and José María Yagüe for the manufacturing of the box enclosure.

Appendix A: Datasheets

The AD8302's datasheet is available at the analog devices web page:

http://www.analog.com/static/imported-files/data_sheets/AD652.pdf

An interesting tutorial on Votage-to-Frequency converters is:

W. Kester, J. Bryant: "Voltage-to-Frequency Converters". Analog Devices Tutorial MT-028. Available at: http://www.analog.com/static/imported-files/tutorials/MT-028.pdf.