LOW COST FREQUENCY METER BASED ON CD 4026

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Abstract: *This paper presents a study about building a simple and cheap at-home frequency meter based on the classical CD4026 integrated circuit. The present device is designed to measure the frequency of a low voltage analog signal. It will be shown that, in a great number of situations, this device can successfully replace an oscilloscope. Because of its smaller price, it can be used in electrical engineering schools in a number of experiments, as a good replacement for oscilloscopes.*

1. INTRODUCTION

A frequency meter is a device that measures the frequency of an AC voltage signal and shows the measured value on a display [1]. The key point for building a frequency meter is to make it very simple to use, reliable and small.

In principle, the general architecture of a frequency meter is made up of three main basic subsystems, as shown in Fig. 1. These are:

- the counter block - through which the device counts the number of pulses present on the input side;

- the monostable blocks - through which the device enables and disables the counting period and controls the reset feature built-in for CD4026;

- the power supply block – which consists of a 7812 voltage regulator and some capacitors;

A frequency meter must be able to measure the frequency of an alternative signal source easily and without additional circuitry [2]. The main operation realized by such a device is called counting. The counting feature is enabled for such a device for a fixed period of time. In the case of the device presented in this paper, this period of time is of one second. Fig. 1 presents the simplified block diagram of operation for a frequency-meter. The same blocks, along with their interior electrical components, can also be noticed in the extended diagram of Fig. 2.

The most important components of the diagram in Fig.2 are the six CD4026 integrated circuits, which are placed on the diagram immediately under the 7-segment displays. They have in fact a double function: they work as decade counters, and also as decoders for the 7-segment displays.

The CD4026 integrated circuit (IC) belongs to the 4000-series family of integrated circuits, which is CMOS logic based. The first devices of this family were produced in the late ‘60s and were logical gates, flip-flops and counters [3]. Besides the CD4026, this family contains many other counter circuits, as for example 4017, 40110, 40192 and 40193.

The main advantage of the chosen counter is that it can drive a common cathode 7-Segment display directly, without the need for addition circuitry. Another advantage is that it is TTL-compatible and thus can be interfaced with a great number of timer and microcontrollers. It also can be easily cascaded with more integrated circuits to display higher range of frequencies. Another advantage is that it can be found in a great variety of 16-pin packages, like PDIP (Plastic Dual-in-Line Package). Another characteristic of this circuit is that it has a maximum measurable frequency of 6MHz. Comparing to modern counters, this seems like a low number, but because it is designed especially for electrical-engineering school-laboratories and low-frequency counting application, this frequency is considered sufficient.

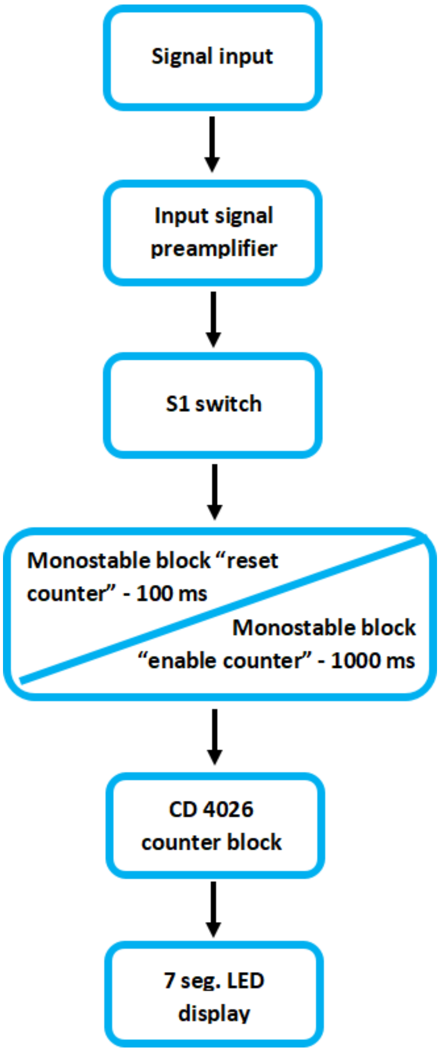

Fig. 1 General architecture of a frequency-meter

2. ELECTRONIC COMPONENTS

Returning now to Figure 2, this image shows the detailed main circuit diagram of the frequency meter. The blocks that can be observed in this figure are:

- the power supply block – which is feeding 12V regulated output to all the other blocks;

- the CD 4026 counter and display block - which is the main block and which is the one that counts and shows the frequency applied to the input side.

- the input signal preamplifier is made of two transistors that amplifies the input signal. Thanks to this block, one can apply a wide range of voltage signals to the input side, varying from 2 to 24 volts peak to peak;

- the monostable reset block is the one that resets the counter to "0".

- the monostable enable counter block is the one that enables the counting process for one second; the need for this time interval will be explained in the testing section.

The main electronic parts needed for manufacturing of this device are succinctly presented below:

- six CD 4026 ICs; these are the integrated circuits presented at length in the introduction [3]

- six KW1-521coa 7 seg. LED displays; they are used to show the measured frequency;

- two NE555 timers used for the two monostable blocks [4];

- six BC546 NPN bipolar junction transistors;

- one BC556 PNP bipolar junction transistor;

- one L7812 voltage regulator IC used in the power supply block;

- other passive elements shown in the circuit diagram (capacitors, resistors and trimming resistors);

- one PCB test-board;

The total price of the above components amounts to little more than 25€, demonstrating the initial affirmation as to the low cost of the device.

3. SPECIFICATIONS

This section of the paper deals with the instructions on how to use the device, detailing also its nominal parameters. The final device, put together on a PCB test-board, can be seen in Fig. 3. The user must first connect the signal source (sine, square or saw tooth waveform signals) to the input connector (Fig. 3), then press the S2 button (the button found on the second monostable block of Fig. 3), then wait for 1.1 seconds. The frequency will thus be measured and immediately shown on the 7 segment LED display [5][6].

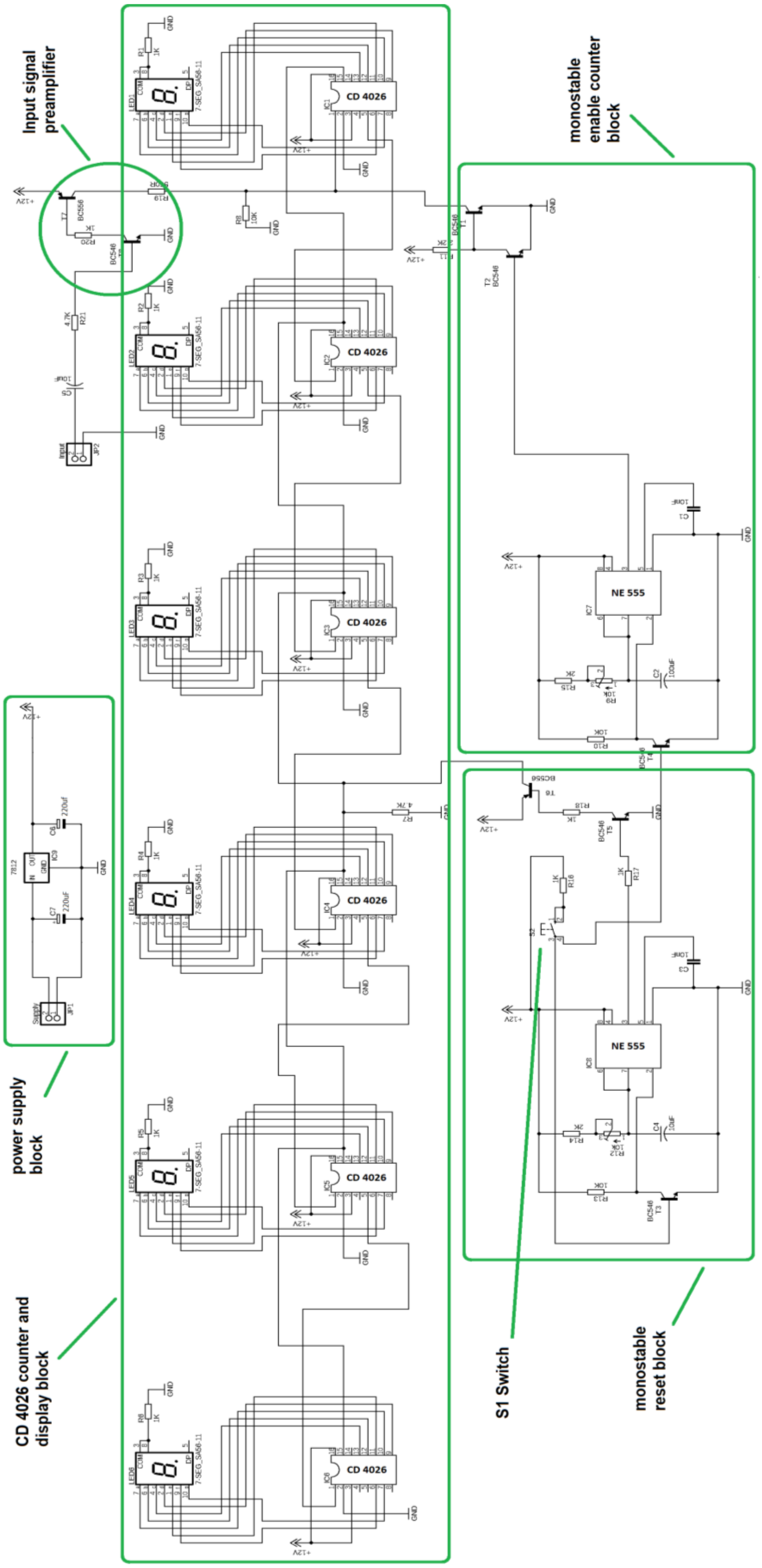

Fig. 2 Detailed circuit diagram of the frequency meter

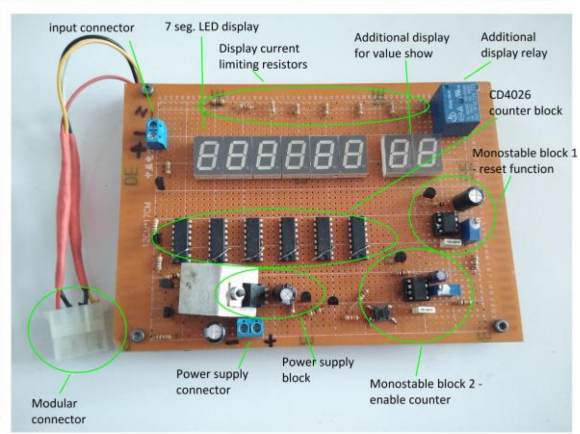

Fig. 3 – Final device put together on a PCB test-board

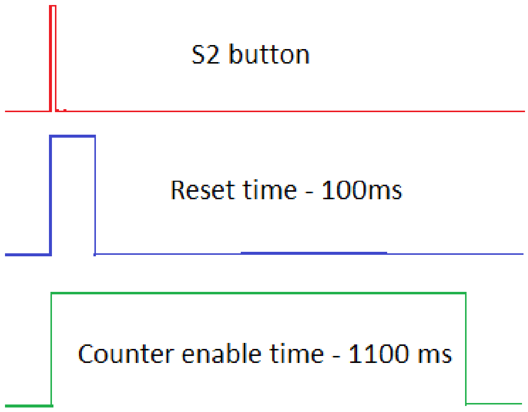

Fig. 4 – Calibrating the activation time for the two monostable blocks

The total dimension of the board in Fig. 3 is equal to 12cm x 17cm. The supply voltage must fall in between 14 and 24 Volts [7]. The current consumption of the device is 150mA. Considering the limitations introduced by the different components of the circuit, the total measuring range of the input signal covers all the frequencies from 5Hz to 50kHz. Meantime, the amplitude range of the input signal must be between 2 and 24 Volts peak to peak and needs to be capable to deliver at least 200µA of current. Lower than this and the device may not pick up the oscillations, while if the amplitude is higher than this, it may burn up the integrated circuits.

Overall the output measured value shown on the display has an accuracy of about ±5%.

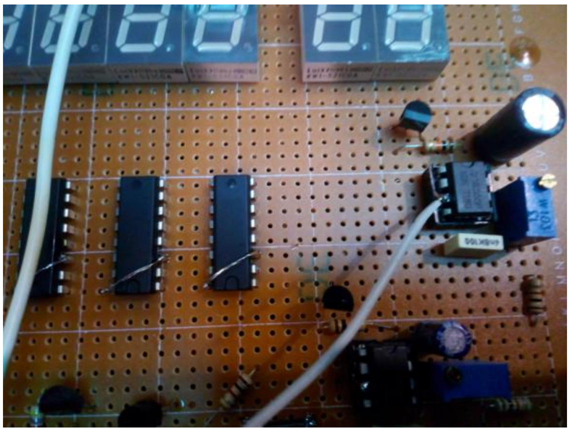

Fig. 5 – Connection of the oscilloscope to the frequency-meter for calibration

4. DEVICE CALIBRATION AND TESTING

The device calibration was done using an oscilloscope. In this process, the activation time for the two monostables of Fig. 2 was adjusted [8][9] as shown in Fig. 4. The scope was connected to the output pin of each 555 IC [8] of the two monostable blocks as shown in Fig. 5.

An activation time of approximately 100ms was chosen for the reset monostable and another time of 1100ms duration was adjusted for the enable counter monostable. This later time includes also the 100ms reset time. Fig. 6 and Fig. 7 show how the actual adjustments were made using an oscilloscope [10].

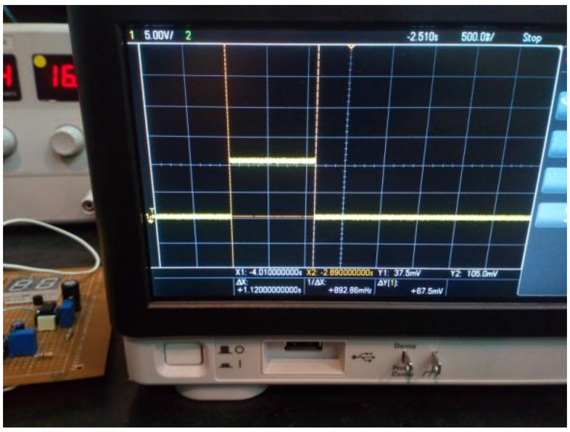

Fig. 6 – Monostable enable (500ms/div)

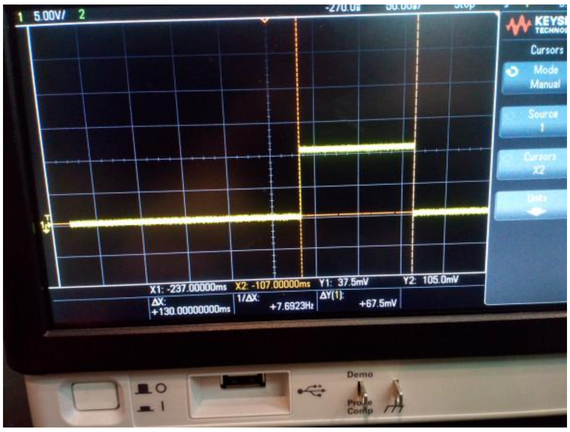

Fig. 7 – Monostable reset block (50ms/div)

The device was tested using three different waveforms (saw tooth, square-wave and sine-wave signals) that had a frequency between 5 to 50.000 Hz. During this test the maximum frequency that could be measured was found to be 50Khz. Another unanticipated fact noticed during the tests was that the device was sensible to electromagnetic radiation. It thus can wirelessly measure the frequencies of high voltage currents circulating nearby. If one keeps the actual device close enough to a 220V wall socket, it can measure the frequency of the current present at that socket, which in the region where the tests were conducted is around 50Hz.

5. PRACTICAL APPLICATIONS

As stated in the abstract of the paper, the author designed this device as a learning material for entry level students. Because of its frequency meter capability, it can successfully replace oscilloscopes in laboratory setups in which only the frequency of the signal is of interest, instead of the amplitude or the waveform. Due to the very simple principle of operation of this device, explained in the third section of the paper, the students will know operating it very quickly comparing to an oscilloscope.

In setups outside college laboratories, it can be used whenever a quick frequency measurement is needed. It is great for measuring PWM (pulse width modulated) signals and other frequency-stable signals.

6. COMPARISONS

The technical literature abounds with examples of low-cost frequency meters, analog or digital. A typical selection of such frequency-meters [11-18] will allow some comparisons with the one presented in this paper.

The first of the selected papers [11] describes a new type of frequency-meter, based on a novel method for measuring frequency based on power measurements. It works at higher frequencies than the present paper frequency meter, but it has lower accuracy.

Another low cost frequency meter is based on digital components [12]. This can be home made as the schematic has the same level of complexity as the frequency-meter presented in this paper. The price range and the frequency range are comparable to the present paper frequency-meter, as both variants use the NE555 Timers.

Another possible architecture for a frequency-meter is based on microcontrollers [13]. These are limited by the counting capacity of the microcontrollers and low-cost ones have lower frequency ranges [13] than the one presented in this paper. Their advantage is that they are easily programmed and can also be home-made.

Another frequency meter based on the NE555 [14] that can be home-made has also the advantage that it can be easily converted into a light-meter. This particular schematic differentiates from the present paper frequency meter by its pure analog display using a meter needle.

A professionally made frequency meter, the PTS2600 [15], is a low cost professionally made microwave frequency counter. It measures frequencies between 40Hz and 20GHz, thus it can also measure microwaves. Considering it is professionally made, this one has many advantages over all the other frequency meters presented in this paper, including the greater frequency range and greater accuracy. The single disadvantage of the PTS2600 is that it is proprietary and thus it cannot be constructed at home. In fact, it is more difficult to find at-home built frequency meters if radio-frequencies or microwave frequencies must be included in the measuring range. One such rare example [16] is a low cost frequency meter for microwave frequencies. It has surprisingly good accuracy, with just 116Hz error when measuring a 6GHz signal. Another last example of microwave frequency meter which can be built at-home [17] uses an easily programmable 8-bit microcontroller PIC16F876A.

Coming back to lower frequency ranges, there are in the literature many frequency meter schematics which can be implemented at home, from the simplest ones [12],[14] to more complex examples [18]. The advantage of the schematic presented in this paper resides in its simplicity of execution which exceeds all the reviewed schematics of this section [11-18].

7. CONCLUSIONS

This paper shows how the “old fashion” electronics can still be of use in today’s world. This device is a proof of the fact that we can make useful, simple and reliable gadgets using a cheap selection of electronic parts rapidly put together on a PCB test board using a proper schematic diagram. The total price of the components used to build the frequency-meter presented in this paper barely reaches 25€. A surprising fact noticed during the test phase was that the device is capable of wirelessly measuring the frequencies of high voltages nearby. The maximum frequency which was correctly measured by this device during the test-phase was 50KHz.

The device presented in this paper can be improved and extended in other fields of interest by using some intermediate modules that could convert any other physical quantity (temperature, noise level, pressure, light intensity, wind power, etc.) to a frequency that is directly proportional with that physical quantity. Using simple mathematics, the value of the signal that is measured can be thus displayed using this frequency meter.

8. REFERENCES

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