International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 7, Issue 6, pp 1-4, June-2023

https://doi.org/10.47001/IRJIET/2023.706001

Development of Affordable Portable Oscilloscope Using Vacuum Tubes

Maximilian Aaron Jelačić

Katolički školski centar Sv. Josip Opća-realna gimnazija, M. P. Sokolovića 11, 71000 Sarajevo, Bosnia and Herzegovina

***Abstract* - The goal of this project is developing an affordable oscilloscope for the average hobbyist and making it simple to use and build. The developed oscilloscope is an analog oscilloscope. Because they are much simpler to build than digital ones, they are generally more resistant to high voltages and allow the user to measure voltages up to hundreds of volts without damaging the oscilloscope. This gives the user a greater freedom in experimentation. As the oscilloscope is an analog one the display will be provided with a cathode ray tube. Having a CRT display makes the driving circuit of the display much simpler than a digital one. To allow the oscilloscope to handle high voltages and to be able to power the x and y deflection on the CRT, vacuum tubes will be used. Even though vacuum tubes consume and waste power for the heating of their cathodes, that will only present a couple watts of loses that can be ignored in this prototype development.**

Keywords: Vacuum tube, oscilloscope, CRT display, prototype.

I. INTRODUCTION

Oscilloscopes, also known as oscilloscopes or scopes, are electronic instruments used to observe and analyze electrical signals. Oscilloscopes are widely used in various fields, including engineering, telecommunications, and medicine. The history of oscilloscopes can be traced back to the 1890s when Karl Braun developed the first cathode-ray oscilloscope. The invention of the vacuum tube in the early 1900s paved the way for the development of more advanced oscilloscopes. With the advent of digital technology in the 1960s, digital oscilloscopes became available, offering greater accuracy and reliability.

There are two main types of oscilloscopes: analog and digital. Analog oscilloscopes use a cathode-ray tube to display the signal, while digital oscilloscopes use an LCD or LED screen. Digital oscilloscopes offer greater accuracy, reliability, and features such as memory and signal processing. However, analog oscilloscopes are still used in some applications due to their simplicity and low cost.

Oscilloscopes have many applications in various fields. They are used in electronics to measure voltage, current, and frequency of signals. In telecommunications, oscilloscopes are used to analyze signals in communication systems. In medicine, oscilloscopes are used in electrocardiography (ECG) and electroencephalography (EEG) to measure and analyze electrical signals in the human body. Oscilloscopes offer many benefits, including the ability to measure and analyze complex signals accurately, making it easier to diagnose and fix problems in electronic systems. They also offer greater functionality than other measuring instruments such as multimeters, providing more detailed information about the signals being measured.

However, oscilloscopes also have some limitations. They can be expensive, and digital oscilloscopes require more specialized training to use and interpret the data correctly. Additionally, oscilloscopes may not always accurately represent the signal being measured due to limitations in their bandwidth and sensitivity. In conclusion, oscilloscopes are essential tools in electronics, telecommunications, and medicine. They offer accurate and reliable measurements of complex electrical signals, making it easier to diagnose and fix problems in electronic systems. With further technological advancements, oscilloscopes will continue to improve, providing even greater accuracy and functionality.

Vacuum tubes are the earliest active electronic components. They were developed at the beginning of the 20th century. They work on the principal of thermionic emission or the emission of electrons by a heated material under vacuum. Vacuum tubes consist of two primary electrodes: a heated cathode and an anode also known as the plate.

The elemental vacuum tubes are the diode and the triode. All other vacuum tubes can be seen as variations on these two. For instance, rectifiers, some VFDs, x-ray tubes can be seen as variations of the diode (they consist of a cathode and anode but no control grid), whereas tetrodes, pentodes, CRTs and other similar tubes can be considered modified triodes (they consist of a cathode, anode and other electrodes (grids) that control electron flow).

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 7, Issue 6, pp 1-4, June-2023

https://doi.org/10.47001/IRJIET/2023.706001

II. METHOD

Even though an analog oscilloscope can be made by using solid state technology, the high voltages the cathode ray tube uses can damage the components. The signal amplifiers used to power the deflection plates of the CRT require high voltages that make using common low voltage transistors practically impossible. That is why using vacuum tubes for a simple CRT oscilloscope is much simpler.

As a saw tooth (X) oscillator an EF80 RF pentode (Fig. 1) is used with a rotary switch that chooses the frequency range at which the oscilloscope will measure. The oscilloscope has 5 ranges, which are selected by the switch (Fig. 2). The time base is about 100ms to 4us (frequency of X deflection approx. 10 Hz to 250 kHz).

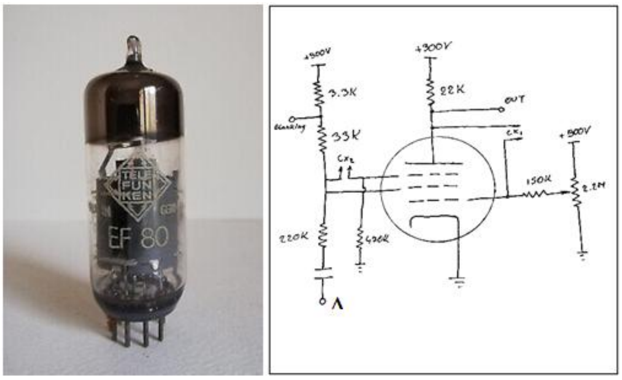

Figure 1: EF80 RF pentode (left) and the EF80 tube oscillator circuit used (right)

The scan frequency is changed by a 2.2MΩ potentiometer as shown on the circuit. The scan frequency range is changed by changing capacitors cx1 and cx2 with a rotary switch.

Figure 2: The switch

As a symmetrical driver of X and Y plates a soviet 6n1p double RF triode (Fig. 3) is used. The second 6n1p tube serves as a two-stage amplifier (Y). Unbalanced deflection would be simpler, but it causes poor sharpness of the line (it would be impossible to focus the bean on entire screen, but only on part of it). That's why symmetrical deflection was chosen.

Figure 3: 6N1P vacuum tubes (center) with detection amplifier (left) and input amplifier (right)

The needed voltages for the CRT and the vacuum tubes are provided by a voltage double circuit that takes 250V from the power transformer and provides 300V for the vacuum tubes and a negative voltage of 300 to 400V for the cathode of the CRT (Fig. 3). Control elements are only brightness, range, X-frequency, sensitivity, and focus.

Figure 4: 5LO30I cathode ray tube

The power transformer is a 30W toroidal transformer obtained as a vacuum tube amplifier transformer. It has 230V primary and 3 secondary coils. The outputs are 250V and two times 6.3V. One of the 6.3V outputs is used for the CRT filament and the other for the rest of the vacuum tubes. This must be done because the voltage differential between the cathode of the CRT and the tubes id more than 300V which can cause arcing in the tubes and destroy them.

III. RESULTS AND DISCUSSION

During development a neon discharge lamp relaxation oscillator was used, but that circuit proved to be inadequate for the task (Fig. 5). The neon discharge lamp used was a typical

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 7, Issue 6, pp 1-4, June-2023

https://doi.org/10.47001/IRJIET/2023.706001

Ne2 glow indicator. The problem was that the firing voltage of the discharge lamp changes after every strike because of temperature and pressure change in the bulb. This causes a saw tooth wave that has a slightly changing frequency that causes a blurry and shaky image on the screen.

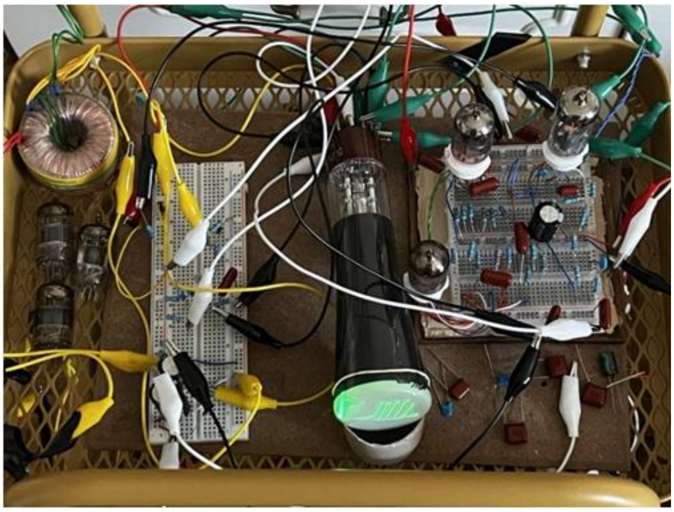

Figure 5: Oscilloscope in development

The first horizontal oscillator used for the oscilloscope was a neon indicator saw tooth oscillator. It worked by charging a capacitor throw a large resistor and having a neon indicator lamp discharge it creating a saw tooth waveform. The problem with this was that the neon lamp would fire irregularly, and it was very sensitive to interference from the ambient light. These irregularities caused a shaky picture that was hard to look at.

The pictures below show the oscilloscope with the old and new deflection oscillator.

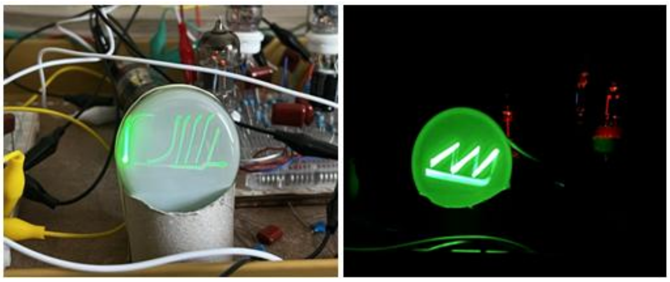

Figure 6: Oscilloscope with unbalanced deflection (left) and oscilloscope with balanced deflection (right)

As previously mentioned, an unbalanced deflection circuit causes a bad picture. In early stages of development, the oscilloscope used a push-pull amplifier for deflection but balancing the two ends of the circuit proved to be difficult and resulted in a deformed picture.

To solve the problem vacuum tubes were used to correct the deflection and improve the output image (Fig. 7 and 8).

Figure 7: Connected vacuum tubes

Figure 8: Vacuum tubes inside the oscilloscope in operation

The final oscilloscope is light weight portable and practical for use by any hobbyist (Fig. 9). The simplicity of the circuit and the vacuum tube technology used provides the user with the ability to service modify and improve the oscilloscope to their needs (Fig. 10).

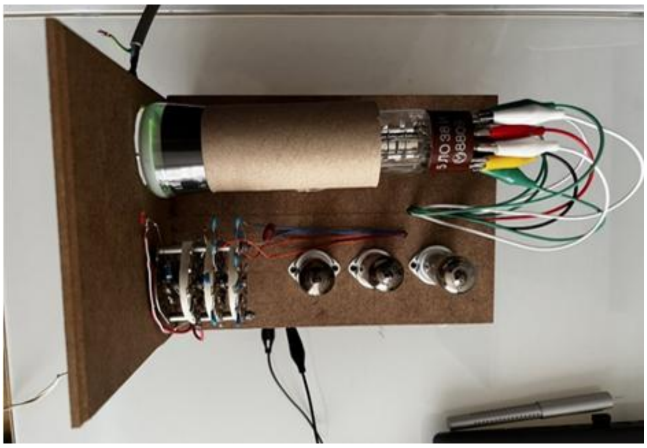

Figure 9: The final oscilloscope prototype

ISSN (online): 2581-3048
Volume 7, Issue 6, pp 1-4, June-2023
https://doi.org/10.47001/IRJIET/2023.706001

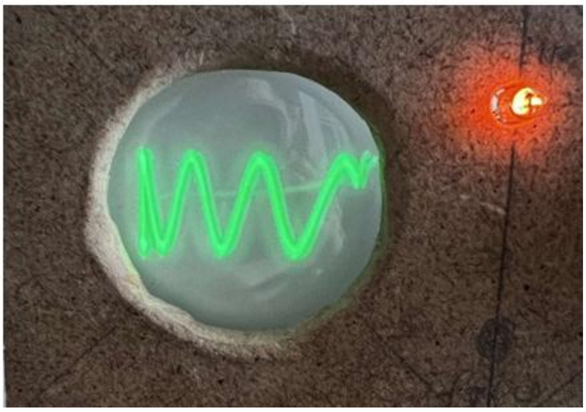

Figure 10: CRT displaying a sine-wave

IV. CONCLUSION

The set goal of developing and making the portable oscilloscope has been met. During the development several problems in the output signal presented on the cathode ray tube screen have been solved and optimized.

REFERENCES

[1] https://www.engineering.com/story/vacuum-tubes-the-world-before-transistors
[2] https://circuitdigest.com/article/what-is-vacuum-tube-and-how-does-it-work

AUTHOR'S BIOGRAPHY

Maximilian Jelačić is a high-school student who has several awards in science, physics and mathematics. He won gold medal in International Science Project Olympiad, is national champion in physics and science. He qualified to participate in IPhO 2023 in Japan as the youngest participant. His hobbies are electronics and chemistry.

Citation of this Article:

Maximilian Aaron Jelačić, "Development of Affordable Portable Oscilloscope Using Vacuum Tubes" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 7, Issue 6, pp 1-4, June 2023. Article DOI https://doi.org/10.47001/IRJIET/2023.706001

****

