M Y F I R T A T V S Y S T E M

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INTRODUCTION

It is not a simple longing for the old days, but the worldwide ham radio activity has lost much of its experimentation characteristics. Now-a-days most of the operators are formed by efficient 'button pressers' only. It is a pity because the technical development is one of the main functions of our activity and, by some commercial and economical reasons, it cannot belong to our activity as before.
In 1964, I and my namesake (PY1BAV of the old times) decided to build an ATV system. The great problem was that we were students and, therefore, 'broken', not being possible to buy the camera tubes that were, at those times, very expensive ('web cams' that, we have now, digital and with no sensor tube, didn't exist; there were only vidicons and the image orthicons). The challenge was there: to develop an 'eye' for our camera but accessible to our budget. In that time IC's didn't exist and even silicon transistors were very common.

THE CHOSEN SYSTEM

In an electronic material surplus I got tube 1P22 (I got two, indeed), a photomultiplier showed in Figure 1.
Eu consegui, em sucatas de equipamentos em algum ferro velho de material eletrônico, uma válvula fotomultiplicadora do tipo 1P22 (aliás, consegui duas!) mostrada na figura 1.
This is a light sensor with internal amplifier using 9 dynodes (few people know what this is, but see the appendix about the subject) as signal internal amplifier with rather fine sensitivity.

Figure 1

To start, many problems arose. In first place, we needed to learn how to design and build good video amplifiers, as that was the signal type which we would deal with; after, we had to use the resources we had, as tubes and other components to build our TV transmitter, especially as to video modulation issues; finally we had to generate our own video signal, as to produce our images was our intention. For the first stage, the video amplifiers development, we used the system showed in Figure 2.

First stage:

Using a TV, tuned at the channel of the best image, we assembled the system with the 1P22 'watching' a TV screen and generating a video signal identical to that of the TV. Synchronizing pulses were taken from the respective circuits of the TV set. Blanking pulses were generated at the photomultiplier itself, as, when the screen turns off during the retrace, the video signal in the 1P22 goes to the maximum black. The video signal so generated was amplified and, together the vertical and horizontal synchronizing signals, was sent to the view finder image tube, that, in our case, was a small oscilloscope 2AP1 tube, with green phosphor (the color was not the more suitable, obviously, but it was the only available on our shelves), as in Figure 3. So, it was possible for us to learn to build video amplifiers with gain and pass-band suitable to the project.

Second stage:

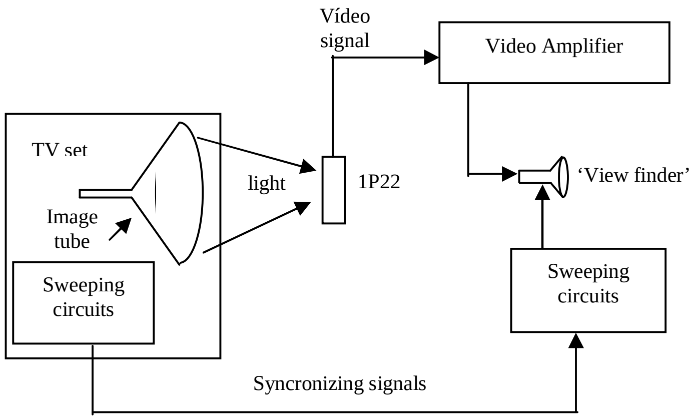

Figure 2

We had already the initial project sketch, but we were not generating our own image nor transmitting via RF yet. We departed to the TV transmitter, as we didn't know how to modulate RF with video. To do it, without producing our own video signal and even with no UHF TV receiver (the 420MHz band was that of the lowest frequency permitted for ATV), we went on using the same TV set video signal and built a very low power transmitter and with no antenna and at a void commercial VHF TV channel (at that times there were some!). We opted, in this case, to use a pentode tube, the 1614, at the RF part. It is similar to the metallic 6L6 (this is a tetrode), but with an independent suppressor grid (a pentode, therefore), but that works fine on VHF. After some experiments, we concluded that the easiest manner for modulating this RF (the video modulation is an AM) was via suppressor grid and, fir that, we use a 1613, a pentode similar to a metallic 6V6 (tetrode). Both the 1614 as the 1613 we had in our 'stock', come, as always, from electronic junk-yards that there were in Rio de Janeiro city. The modulation control adjusted the image quality because kept the signal level within a fine linearity range[1]. Our video amplifiers excited the 1613. After have learned about video modulators, we built a transmitter for 420MHz to be possible to radiate our real signals and we modified an UHF TV set to receive the signals of the amateur band.

Figure 3

Third stage:

So far many problems were solved, but the main problem, that is the real reason of this article, that is, our own video generation, was not solved yet.

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[1] **The modulation is an essentially non-linear process, but here we refer to the fidelity between the modulating signal and the envelope of the video RF (video modulation is an AM).**

As part of the third stage, as the 1P22 could 'see' perfectly a TV screen image, we built a camera only for transparencies or slides. For this, using a TV CRT that we had on our shelves, an 8XP4, Figure 4, not very suitable for that finality[2], we generated only a white screen (with sweepings, but with no image). This screen was 'seen' by the 1P22 as always. When putting a photographic slide or transparency leant against the screen, the video signal was generated because the more transparent areas excited the photomultiplier, rather than the opaque ones. Even putting the hand on the screen, it was possible to transmit a 'black hand' to the receiver by the simple blocking that the hand offered to the screen light. We were already, thus, generating our own video signal *without any conventional camera tube*, but they were not 'alive images' as in a TV station. See it in Figure 5.

Figure 4

Then we reached the second part of our third stage, the most important among all.

In the old times, there was a TV set called 'projection TV'. Rather than using a normal size CRT, where we would see the image, it used a small one (around 3" or less) with high bright because it used a very high acceleration voltage (around 25 kV) and an optical system with a parabolic mirror that focalized the small tube image on a semi-transparent screen (made of a material very similar to that of used in drums), from its back and, on its front one could see perfectly the image[3].

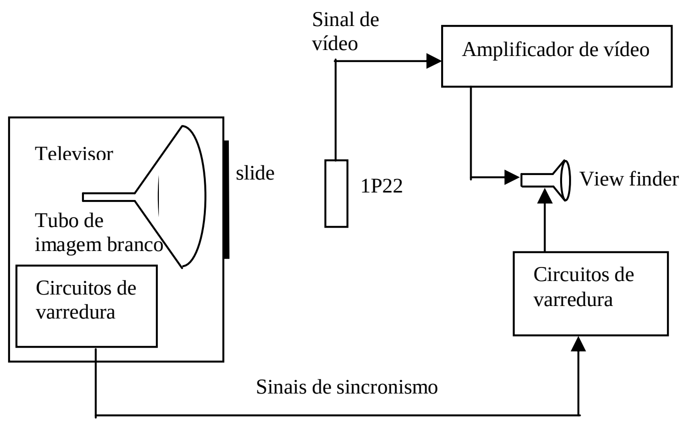

Figura 5

They used high bright because the size gain got with a passive optical system (with no real power gain), corresponded to a small bright on the screen (total power conservation).

Well, if the optical system was able to focalize the image of the small tube on the screen, it could do it on any object (one's face, for instance). We did that. Using an old Philips projection TV, got at a TV repair workshop scrap, we succeeded in focalizing the light from the point that swept the small

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[2] **This tube is only suitable for video system tests, as it doesn't have any ion trap. Its continuous use generates an ionic spot on the screen. We intended to replace it by a more suitable one.**

[3] **This complicated process was used because it was very expensive to manufacture big CRTs with big magnetic deflection angles and small deflection angle tubes had to be used and that made the TV set to grow too much to the back, increasing the set volume. The electrostatic sweeping presents insulation problems, yet more serious, as it happens with oscilloscopes, but with much higher voltages.**

tube on an object, and, using our 1P22, to watch to the reflected light from that object. The clearer points of it generated a greater signal on the 1P22 and the weaker ones generated smaller signals, that is, with this process, we had from the 1P22 the video signal relative to that object! If the latter was a human face, we got his image. See Figure 6.
Our project changed from a transparency TV system to another by reflection, a great step.
Our old projection TV from scrap, came with sweeping, high voltage and CRT feeding in perfect conditions. The sound, IF's and tuning circuits were in bad shape, but they were not needed. The tubes of that TV set were Philips of loctal type yet, that is, very old, but they worked fine. The vertical and horizontal sweep circuits had a protection system such that, if one or both sweepings failed, the little CRT electron beam would be cut off as the beam's great intensity on a single point or line would destroy the phosphor of the region by evaporation of the fluorescent material.
Using video tubes with low persistence (as those with blue phosphorous P5, P22B or the green-blue P15) we get a much better image quality because each spot on the tube is less influenced by the other ones still flowing due the persistence.
Although we have 'invented' this process for video generation with no image tube, it had been much before (we didn't know it in that time) and was called 'flying spot scanner'. It was invented in 1922 and used in old studio TV systems in 1956 (color TV's!).

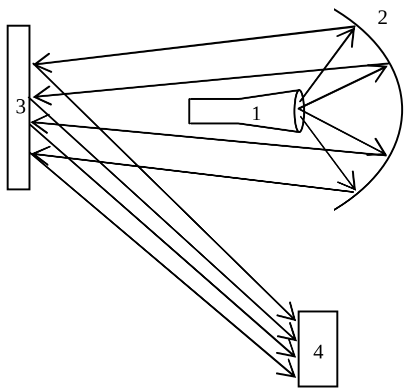

Figure 6: 1 – high brightness image tube; 2 – parabolic mirror; 3 – object to be scanned; 4 – photomultiplier 1P22
The light, coming from the bright spot that sweeps the tube, reflects on the mirror also reflecting on the object to be showed and generating the video signal, accordingly the reflectivity of the point of the object reached by the light.

APPENDIX

Wha is a photomultiplier tube? How does it work?
In the 19th century a physical phenomenon called photoelectric effect was discovered. This effect was the production of electric charges when the light reached metal surfaces. It was badly explained theoretically, but Albert Einstein was who first solved that problem. He, using Max Plank theory, suggested that the light radiations (indeed all electromagnetic ones) are formed by packets of energy proportional to their frequencies, with the light intensity given by the number of such packets. This explained why only some colors (frequencies and, therefore, energies) were able to produce photoelectric effect and other weren't.
If a special metallic plate[4] in the vacuum (for the charges to move freely) is connected to the negative pole of a DC supply and there is another one connected to the positive pole, when the light reaches the first plate, the liberated electrons from it by the photoelectric effect are attracted by the other plate, producing, then, an electric current. If the anode is fed via a resistor, it will be produced an output voltage proportional to the intensity of the incident light.

[4] **The plate is special because the chosen metal to cover its surface must have low electron's binding energy, that means, even low energy packets, as those of visible light, are enough to liberate the charges.**

But, for a very weak light intensity, as that received after a reflection on a scene (people, etc) of a light ray from a TV tube, this output signal is very low[5] to be used by the available amplifiers and we get a very deficient signal-to-noise ratio (video with 'drizzle'). For getting higher signals, we need another type of sensors, with more gain. Here photomultipliers appear.

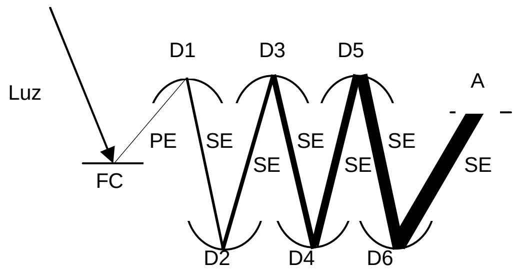

Figure 7: FC = photocathode; D's = dynodes
FE = photoelectrons; ES = secondary electrons;
A = anode
The quantity of secondary electrons is represented by the line thickness.

Photomultipliers are special types of photosensitive tubes with an internal gain system through a set of electrodes called dynodes. Now-a-days their use occurs in certain fields as, for example, the experimental nuclear physics.

As in Figure 7, the tube has a photocathode (metallic plate covered with a special metal), a series of dynodes (intermediate electrodes) and an anode.

The light reaches the photocathode that produces an electron emission (photoelectrons) with quantity proportional to the light intensity[6].

Due the potential difference between the first dynode and the photocathode (dynode more positive), the photoelectrons are accelerated and reach the first dynode that emits secondary electrons in a greater quantity than that of the photocathode. These secondary electrons are accelerated in the direction of the second dynode that has potential greater than the first one. This second dynode also creates secondary electrons in a quantity still greater and so on until the last dynode that emits its electrons to the anode, where the output signal is developed through load impedance connected to the higher potential among all. So, even a small light intensity can produce large signals on the anode, that is, it is a very sensitive system.

Normally the dynodes are fed through a resistive voltage divider between the terminals of a high voltage power supply. To avoid insulation problems[7], his voltage has its positive pole connected to the ground and the negative one to the photocathode, as in Figure 8.

Normally all resistors of the divider are equal, but the system linearity, that is, the proportionality between the light intensity and the output signal, is controllable by adjusting the resistors of the higher dynodes that handle greater currents and have potential nearer the ground.

The load RL is in most cases not a pure resistor but a combination of resistor-inductor (peaking coil) for a higher gain and good pass-band (high frequency response), specially in video circuits.

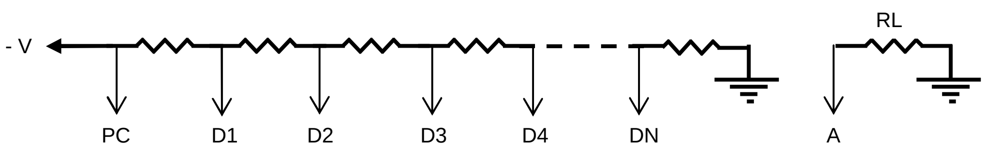

Figure 8

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[5] **A higher value resistor could be used to increase the signal, but due the involved circuit capacitances, that resistor would lead to a poor high frequency response, something fatal for the rapid video signals, corresponding to the fine details on the scenes. So, we have to use low value resistors with the consequent low signal amplitude.**

[6] **The sensitivity of the photomultiplier is also dependent on the color of the light radiation. Below certain frequency, the 'packets' don't have enough energy to pull away the electrons from the atoms.**

[7] **As the output is on the anode, if this is connected to a too much high potential as to ground, the coupling capacitor that follows has to support high voltage and also a large pulse is transmitted to the amplifier when the power supply is turned on.**

CONCLUSION

I hope this article has been successful in his sakes, specially that of showing to the readers that, even without much resources, it is possible to develop very interesting and efficient systems.
It is a question of thinking in how to solve a new peoblem that shows up to the person, that is, development is a question of atitude of a person that faces a new problem.