
Subject: Tubes versus Transistors

Posted by [Wayne Parham](#) on Mon, 21 Feb 2022 16:24:01 GMT

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I enjoyed a little "garage find" this weekend. Not an equipment find - not even really a garage find - but a magazine squirreled away for decades.

I've been writing a series of online articles about old computers, mostly eight-biters from the 1970s. I actually hoped to do one about every three months but I kinda went crazy on the first one - the Sym-1 - and so the second one was delayed. But I finally got around to writing this weekend, and uploaded an article on the RCA COSMAC ELF. In the months to come, I'll write articles on the Altair 8800 and the Inmos Transputer.

The ELF was a computer project described in an article written by Joseph Wesbecker, published in the August 1976 issue of Popular Electronics. A photo of the computer is shown on the cover of the magazine, and I reference that in my online article about the ELF.

So now to the point of why I wrote here. Go to the RCA COSMAC ELF page and find the image of the Popular Electronics August 1976 magazine. Click on that and you'll get a PDF file of the whole magazine. Then go to page 14.

It's an article about the differences between tubes and solid state. I had to post that here 'cause we still talk about the very same stuff, almost 50 years later!

Subject: Re: Tubes versus Transistors

Posted by [Rusty](#) on Mon, 21 Feb 2022 17:09:10 GMT

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Beats me but I sure dig my tube gear. But same with my ss gear. Just not as fondly. I didn't know that tube gear was as prevalent as it was in 1976. Like vinyl and phono it just couldn't be made extinct. Maybe because of us baby boomers, but like Pandora's box it's out there affecting younger generations. At the end of the article is an ad for a dot matrix printer. Damn thing looks like it's got a Briggs & Stratton motor on it. Digital really has come a long way from it's infancy.

P.S. Enjoyed looking at your "day job" work, You're on another level Wayne, what you do. And your family photo's.

Subject: Re: Tubes versus Transistors

Posted by [gofar99](#) on Wed, 23 Feb 2022 02:20:05 GMT

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Hi, As long as there are tubes and solid state gear they will be talking about it. I have a considerable amount of each. In my main system there are 4 Oddblocks that provide the muscle

to the speakers. But there is no way I would replace the solid state electronic crossover that splits the sound to the amps. It would take 50 tubes and not be as good. Same thing on my main turntable. I can't even imagine trying to power the motor (an ex Dual 701 ESD1000) with tubes. The heat alone would require its own cooling system. The issue is not so simple in other parts of the system. I have tube and solid state phono preamps. The SS ones gather dust. FM is done by a really slick vintage Sony tuner. Tiny thing with only one sealed metal box in it. The thing made the "B" list for Stereophile. Incredible sensitivity, sound etc and OBW gets HD FM. No way I would swap that for a tube unit. It would be a serious step down.

Now that we opened Pandora's box... the argument of discrete SS components vs IC ones. That is nearly equal in pros and cons. It includes the thoughts of some negative feedback, none or lots (as with ICs). Chomp on that one a while.

My overall take is that (one) there are many ways to do most things (two) each of us has to decide what works best for ourselves. :roll:

Subject: Re: Tubes versus Transistors
Posted by [Wayne Parham](#) on Wed, 23 Feb 2022 16:01:42 GMT
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I'm pretty sure that each of us (regulars) here on ART is in one accord on this. But I was just surprised to find that amplifier article, long lost in my mind. I just had to mention it here, just for fun. It was as fun to read as the computer article I dug it up for.

Subject: Re: Tubes versus Transistors
Posted by [positron](#) on Tue, 21 Jun 2022 02:13:46 GMT
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Wayne, I was wondering if the subject is still open or if most just wish to close it now? Is there still interest in the inherent differences between tube and solid state pertaining to analog components/circuits, and associated parts? If there is still interest, there are still some inherent differences that affect sonic quality.

cheers

pos

Subject: Re: Tubes versus Transistors
Posted by [Wayne Parham](#) on Tue, 21 Jun 2022 13:53:09 GMT
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It's an ongoing discussion and I'm always interested.

I remember, when I was a teenager, thinking that vacuum tubes were an interesting historical oddity, firmly superseded by more modern technologies.

I was surprised to learn - much later - that modern vacuum tube amps weren't made purely for nostalgia. They were made for sound quality too.

Subject: Re: Tubes versus Transistors

Posted by [Rusty](#) on Tue, 21 Jun 2022 14:25:53 GMT

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A/D in the year 1965. What the vacuum tube could accomplish then wasn't any slacker. The end of the video sums it up best. Good engineering is what can be done with what you got. Bell Labs it seems was one of the most productive and innovative engineering works in our countries history.

<https://hackaday.com/2022/06/08/retrotechtacular-the-forgotten-vacuum-tube-a-d-converters-of-1965/>

Subject: Re: Tubes versus Transistors

Posted by [positron](#) on Wed, 22 Jun 2022 03:08:46 GMT

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Wayne Parham wrote on Tue, 21 June 2022 08:53

It's an ongoing discussion and I'm always interested.

I remember, when I was a teenager, thinking that vacuum tubes were an interesting historical oddity, firmly superseded by more modern technologies.

I was surprised to learn - much later - that modern vacuum tube amps weren't made purely for nostalgia. They were made for sound quality too.

Don't worry, many over the years have also thought tubes were somewhat an oddity, including my professors. Fortunately, being older I grew up with tubes, and worked on amps and radios since I was 7 or so. (Am I really fortunate??)

Anyway, with the advent of solid state, I had the opportunity of comparing tube amps vs the newly marketed solid state amps of the 60s on. The sonic difference was clear back then. Fortunately, both tube and SS have improved.

As far as inherent differences I will list some, but this will not be an exhaustive list. Some items will be quite elementary, but I mention them for the general public's benefit.

1. Both tubes and transistors have internal capacitances. Triodes have plate to grid, plate to cathode, cathode to grid. Transistors have collector/drain to base/gate, collector/drain to emitter/source, emitter/source to base/gate. (Corresponding to bipolar, fets, hexfrets etc.)

A capacitor consists of two conductive plates/foils and an insulating material/dielectric. The insulating material has dielectric absorption (DA), and foils a series equivalent resistance (ESR). As the musical signal voltage changes, the DA holds on to electrons when it should not. ESR tends to prevent the capacitor from fully discharging when it should. Both are bad.

A. Tubes use a vacuum, thus with basically zero DA.

B. Transistors use a "solid state" material(s) with a much much higher dielectric absorption figure (DA); maybe 500 or more times higher.

2. Tubes have extremely low impedance/resistance terminations to the leads/pins, so the ESR of the internal capacitances are near zero. Solid state has much higher internal termination impedances/resistances, thus a much much higher ESR.

3. Both have Miller capacitance, the gain of stage times the plate to grid capacitance (drain/collector to gate/base capacitance).

Miller capacitance = $A_v \times C_{pg}$.

A. For triodes, the Miller capacitance can amount to up to 150pf, maybe higher in a common cathode gain stage. This capacitance remains relatively constant.

B. Hexfets are a different story. They have their C_{dg} changing from quite small pf (pico farads) to 1000pf or more for power output Hexfets, depending upon the V_{cc} drain voltage to source. Even a three amp drain rating has quite high capacitance but fortunately output types are generally source followers with gain of less than one. Bi-polars are much better in this respect.

There are ways to minimize the junction capacitance problem, but that usually means more transistors, thus more associated parts in the circuitry.

4. Number of stages can vary. Generally, I see many more stages, with associated parts, with SS than with tubes. However, I have recently seen a SS amp with just two total stages, the same as some tube amps. (Tube amplifiers can also have several stages, with more associated parts.)

5. Power supply differences.

A. A solid state amplifier works at relatively low voltages and high currents. This means that the power supply filter capacitance has to be huge, generally in the 10s of 1,000s of uf. Large electrolytic capacitors create huge problems with high DA, ESR, higher internal inductance, and lower resonant frequency.

(See article "Picking Capacitors" by Walter Jung and Richard Marsh" for more information.)

B. A tube amplifier works with much higher voltages and much less current. This means that the power supply filter capacitance is a factor less than SS amplifiers. The DA is just as large, but the ESR and inductance is generally much less, as there is much less foil to deal with. The resonant

frequency is generally higher.

6. Output to speaker.

A. A tube amplifier generally has an output transformer (OPT). A transformer converts a large musical signal (hundreds of volts) to a smaller signal (like SS outputs produce), and a small musical current (couple of hundreds of milliamps) to a large musical signal (like SS outputs produce) to maximize output power to the speaker. These transformers need to handle a wide range of frequencies in a balanced way, and deal with high voltages. This is not easy but can and has been accomplished.

B. A solid state amplifier generally has no need for an output transformer. They are usually directly coupled to the speaker, thus a possible headache avoided.

7. Longevity concerns.

A. Tubes require a filament and cathode.

B. SS is generally immune, although I have seen a transistor's characteristics change over the years.

8. Integrated circuits (ICs) have a couple of problems.

A. A common voltage source, so frequency dependent signal feedback through the power supply.

B. With so many transistors in a close space, transmission of audio signals from one to another, just like an antenna.

C. The associated internal parts, such as resistors etc, are of questionable quality.

With this information presented, I hope the public has a better knowledge base.

Cheers

pos

ps. I have updated this post so one may wish to re-read it again.

Subject: Re: Tubes versus Transistors
Posted by [positron](#) on Tue, 26 Jul 2022 21:48:50 GMT
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For your convenience, here is a link to the article "Picking Capacitors" by Walter Jung and Richard Marsh, Audio Magazine, Feb 1980.

https://milbert.com/Files/articles/Picking_Capacitors_1.pdf

Open the .pdf for the article.

Notice graph B4, the X axis is frequency rising with the arrow pointed right. The Y axis is Z, the impedance is rising with the arrow pointing up.

From left to right, the line X_c is the capacitive reactance (let's call it ac resistance). Notice the real capacitor's resistance is dropping/sloping down until it touches the X axis, zero ac resistance and stays zero resistance to infinity frequency. That is a perfect capacitor.

However, a real world capacitor is not perfect. Notice at R_s , the line is curving and then rising, now called X_L . At R_s , the capacitor is actually becoming an inductor/choke, with inductive reactance (ac resistance) becoming prominent. (However, there is no dc current flowing.)

Now let's go to figure 7. This shows a few electrolytic capacitors and the R_s frequency. Notice how the line for each capacitor starts to curve at " R_s " and then rises.

Notice most curvature starts below 1,000 cycles per second, less than 1khz and all by 10khz. Of course that is well within the audible range. This is the value of capacitors used in solid state and some tube designs.

Newer capacitors are still quite poor compared to poly type capacitors. Of course, a very small electrolytic capacitor will not come close to matching any poly capacitors in figures 9A-D.

I hope this helps in understanding why electrolytic capacitors are not desirable in any analog electronic components, except well away from the direct musical signal path. This especially includes the decoupling capacitor next to the plate resistor.

cheers

pos

Subject: Re: Tubes versus Transistors
Posted by [Madison](#) on Mon, 10 Jul 2023 04:06:54 GMT
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You really seem to know your stuff, Wayne. Your blog entry about the Sym-1 is incredibly

detailed. I especially enjoyed how you set the scene, so we can put the computer in the context of the time. Very interesting!

Subject: Re: Tubes versus Transistors

Posted by [Wayne Parham](#) on Mon, 10 Jul 2023 14:27:11 GMT

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Thanks for the kind words. We are blessed with the company of a lot of smart guys on this board.

If you liked the Sym-1 write-up, be sure to check out the others too.

As an example, I wrote a version of CP/M for the Altair that supports IDE hard drives and compact flash. The development and debugging in assembly language is recorded there as well. In some ways, it's boring but in others, well, you can see what assembly language debugging was like in the 1970s. High-tech for its day - using an early debugger - just past the time when you single-stepped using the front-panel.
