

audioxpress

ADVANCING THE EVOLUTION OF AUDIO TECHNOLOGY

Market Update

Working with USB-C What Audio Developers Need to Know

By J. Martins

You Can DIY!

Building a Null Tester Device

By Ethan Winer

You Can DIY!

Sigma 100 Satellite/Subwoofer Loudspeaker System

By George Ntanavaras

Sound Control

How to Work With an Acoustical Consultant

By Richard Honeycutt

Hollow-State Electronics

More About Noise in Vacuum Tube Circuits

By Richard Honeycutt

You Can DIY!

Revival of the McIntosh MC30 (Part 2)

By Bruce Brown

Audio Electronics

Searching for a Unicorn Measuring Voltage Regulator Ripple Rejection (Part 2)

By Brian Lowe



PARTS CONNECTION

The Authority on Hi-Fi DIY

Enter code: **AX0817**
in the comments box at
checkout to receive
25% Off
your next order.

**Your #1 Source for
Vacuum Tubes, DIY Parts,
Audiophile Accessories
&
Premium HIGH-END Audio Gear**
(Discontinued • Demo • B-Stock)

CAMBRIDGE AUDIO • MONITOR AUDIO •
CARDAS • REGA • FOCAL • WHARFEDALE •
MUSIC HALL • CYRUS • DEVIALET •
ACOUSTIC ZEN • QED • BDI • SOLID TECH •
APOLLO • TARGET • GRADO

Sales: **www.partsconnexion.com** Inquires:
order@partsconnexion.com info@partsconnexion.com



905-631-5777

1-866-681-9602

905-681-9602



5403 Harvester Rd, Unit 1, Burlington, Ontario, Canada L7L 5J7

Debit, Visa, Mastercard, Amex, PayPal, EMT, Money Order & Bank Draft



1140 Series

Studio-Grade Impedance Matching Transformers

Rooted In Solid ENGINEERING

- Microphone Input
- Microphone Splitter
- Line Input
- Line Output
- Direct Box

- Designed with Nickel alloy cores for high performance and Wide Bandwidth
- Frequency Response: 20 Hz – 20 kHz ± 0.35 dB, (ref. @ 1 kHz)
- Low distortion at levels up to +27 dBu @ 20 Hz
- Excellent Shielding – Mu Metal enclosures
- Line Output Transformers are open style (not Mu Metal)



www.hammondmfg.com



June 2019 ISSN 1548-0628

www.audioxpress.com

audioXpress (US ISSN 1548-0628) is published monthly, at \$50 per year for the US, at \$65 per year for Canada, and at \$75 per year Foreign/ROW, by KCK Media Corp., P.O. Box 417, Chase City, VA 23924, US Periodical Postage paid at Chase City, VA, and additional offices.

Head Office:
KCK Media Corp.
P.O. Box 417
Chase City, VA 23924, US
Phone: 434-533-0246
Fax: 888-980-1303

Subscription Management:
audioXpress
P.O. Box 417
Chase City, VA 23924, US
Phone: 434-533-0246
E-mail: custserv@audioxpress.com
Internet: www.audioxpress.com

Postmaster: Send address changes to:
audioXpress
P.O. Box 417
Chase City, VA 23924, US

Advertising:
Strategic Media Marketing, Inc.
2 Main Street
Gloucester, MA 01930, US
Phone: 978-281-7708
Fax: 978-281-7706
E-mail: audioxpress@smmarketing.us

Advertising rates and terms available on request.

Editorial Inquiries:
Send editorial correspondence and manuscripts to:
audioXpress, Editorial Department
P.O. Box 417
Chase City, VA 23924, US
E-mail: editor@audioxpress.com

Legal Notice:
Each design published in audioXpress is the intellectual property of its author and is offered to readers for their personal use only.
Any commercial use of such ideas or designs without prior written permission is an infringement of the copyright protection of the work of each author.

© KCK Media Corp. 2019
Printed in the US

Moving Together on USB

The most recent Universal Serial Bus (USB) specification updates have consolidated the technology in a big way, allowing for the development of more efficient audio and portable devices—and that’s something that all audio developers need to be aware. A wide range of consumer electronic devices are migrating to USB-C interfaces to support rapidly advancing communication and battery-charging capabilities, as well as smaller design size.

While we wait for more details about the latest USB4 specification announced in March 2019—a major update to deliver the next-generation USB architecture that complements and builds on the existing USB 3.2 and USB 2.0 architectures—we are certain that our readers involved in audio product development will benefit from the Market Update we have prepared for this edition, clarifying what solutions they can consider today and what features can they implement to benefit their users’ experience. No, what we have with USB 2.0 is not good enough, particularly for audio applications. Yes, we need to deal with USB constant specification updates, but more importantly we need to know how to implement USB Type-C connectors, how to leverage the interesting possibilities of USB Power Delivery, and in particular, how to make sure new products don’t become obsolete when they are released.

Among many important initiatives that will not be affected by pending USB4 revisions is the Fast Charging and Certified USB Charger Initiative announced in January 2018 by the USB Implementers Forum (USB-IF). Certified USB Fast Chargers support the Programmable Power Supply (PPS) feature of the USB Power Delivery 3.0 specification and aim to increase the reusability and sharing of chargers across all compliant USB Type-C devices, reduce electronic waste in landfills, and provide a reliable and easy-to-use powering and charging solution for consumers. Certified USB Fast Chargers will be backward compatible with devices that support USB Type-C and USB Power Delivery, to accommodate international regulations that require better energy management and to add features that largely benefit the users.

When it comes to the development of audio products that use the USB interface, it’s important to consider all options currently available. Portable audio devices in particular have a lot to benefit with the latest power and charging features, now readily available. Remember, even though many audio developers will consider that USB 2.0 is “good enough” for their needs, new digital audio designs should take into consideration the new USB 3.2 specification. Yes, there will be an update also for that one, but it will mainly build upon what was defined in the USB Audio Device Class 3.0 document the USB-IF published in September 2016. USB Audio Device Class 3.0 is what establishes the framework for USB Audio over USB Type-C for any type of equipment. It makes it easier to support digital audio over USB, adds capabilities to reduce power consumption, and adds support for new features. And it defines minimum interoperability requirements across analog and digital solutions to minimize user confusion when not all hosts or devices support audio consistently.

With the new update interface, developers can eliminate the need for multiple ports and efficiently deliver data, power and video over a single USB Type-C connector with USB Power Delivery. And consumers are increasingly aware of the evolution, are already demanding fast charging features and they expect to benefit from the convenience of the universal and reversible USB Type-C connector. So, it’s time to ditch those mini and micro USB connectors!

J. Martins
Editor-in-Chief

The Team

President:	KC Prescott	Associate Editor:	Shannon Becker
Controller:	Chuck Fellows	Graphics:	Grace Chen
Editor-in-Chief:	João Martins	Advertising Coordinator:	Nathaniel Black

Technical Editor:	Jan Didden
Regular Contributors:	Bruce Brown, Bill Christie, Joseph D’Appolito, Vance Dickason, Jan Didden, Scott Dorsey, Gary Galo, Gerhard Haas, Chuck Hansen, Richard Honeycutt, Charlie Hughes, Mike Klasco, Ward Maas, Oliver Masciarotte, Nelson Pass, Christopher Paul, Bill Reeve, Fernando Rodrigues, Steve Tatarunis, Stuart Yaniger



OUR NETWORK



SUPPORTING COMPANIES

ACO Pacific, Inc.	35	Linear Integrated Systems	29
All Electronics Corp.	63	Menlo Scientific, Ltd.	59
Avel Lindberg, Inc.	63	NTi Audio, Inc.	13
COMSOL, Inc.	11	Parts ConneXion	2
GRAS Sound & Vibration	17	Parts Express International, Inc.	68
Hammond Manufacturing, Ltd.	3	PCB Piezotronics, Inc.	53
HEAD acoustics, Inc.	41	Powersoft, S.p.A.	9
Hypex Electronics BV	65	SB Acoustics	55
InfoComm International 2019	49	Swans Speakers Kits	35
JLI Electronics, Inc.	33	Triad Magnetics	67
KAB Electro-Acoustics	57		

NOT A SUPPORTING COMPANY YET?

Contact Peter Wostrel (audioxpress@smmarketing.us, Phone: 978-281-7708, Fax: 978-281-7706) to reserve your own ad space in the next edition of the magazine.

COLUMNISTS

Vance Dickason has been working as a professional in the loudspeaker industry since 1974. He is the author of *Loudspeaker Design Cookbook*—which is now in its seventh edition and published in English, French, German, Dutch, Italian, Spanish, and Portuguese—and *The Loudspeaker Recipes*. Vance is the editor of *Voice Coil: The Periodical for the Loudspeaker Industry*, a monthly publication. Although he has been involved with publishing throughout his career, he still works as an engineering consultant for a number of loudspeaker manufacturers.

Mike Klasco is the president of Menlo Scientific, a consulting firm for the loudspeaker industry, located in Richmond, CA. He is the organizer of the Loudspeaker University seminars for speaker engineers. Mike specializes in materials and fabrication techniques to enhance speaker performance.

Dr. Richard Honeycutt fell in love with acoustics when his father brought home a copy of Leo Beranek’s landmark text on the subject while Richard was in the ninth grade. Richard is a member of the North Carolina chapter of the Acoustical Society of America. Richard has his own business involving musical instruments and sound systems. He has been an active acoustics consultant since he received his PhD in electroacoustics from the Union Institute in 2004. Richard’s work includes architectural acoustics, sound system design, and community noise analysis.

Steve Tatarunis has been active in the loudspeaker industry since the late 1970s. His areas of interest include product development and test engineering. He is currently a support engineer at Listen, in Boston, MA, where he provides front-line technical support to the SoundCheck test system’s global user base.

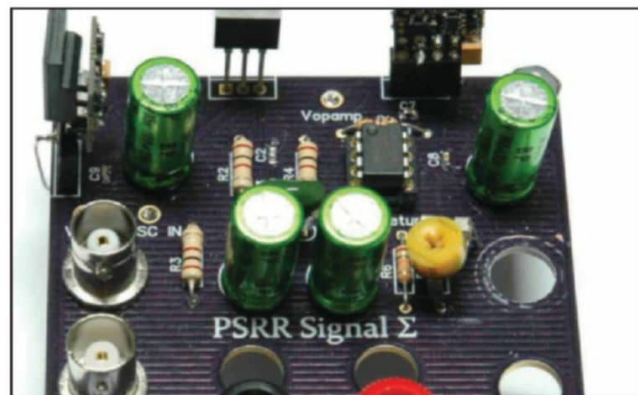
The Audio Voice

Sign up now for our **FREE** weekly e-newsletter



Weekly Newsletter for the Audio Industry, Professional Designers and Audio Enthusiasts
Product Design | Audio Electronics | Acoustics | DIY | Innovations in Audio





● Features

26 Building a Null Tester Device

By Ethan Winer

Ethan Winer details the construction and theory behind his Null Tester, which is a device that sends the same audio signal through two paths, then it electronically subtracts one signal from the other to obtain the difference.

30 Restoration and Revival of the McIntosh MC30 (Part 2)

Finishing the Restoration

By Bruce Brown

In the second part of this article, Bruce Brown discusses some important information, including the power supply rebuild and some improvements you can make to help your MC30 last another 50 years.

36 Sigma 100 (Part 1)

Designing the Satellite/Subwoofer Loudspeaker System

By George Ntavaras

In the first part of this two-part article, George Ntavaras shares his design for the Sigma 100, a unique loudspeaker system with two satellite speakers and a single subwoofer.

50 Searching for a Unicorn (Part 2)

Generating a Good Signal Source

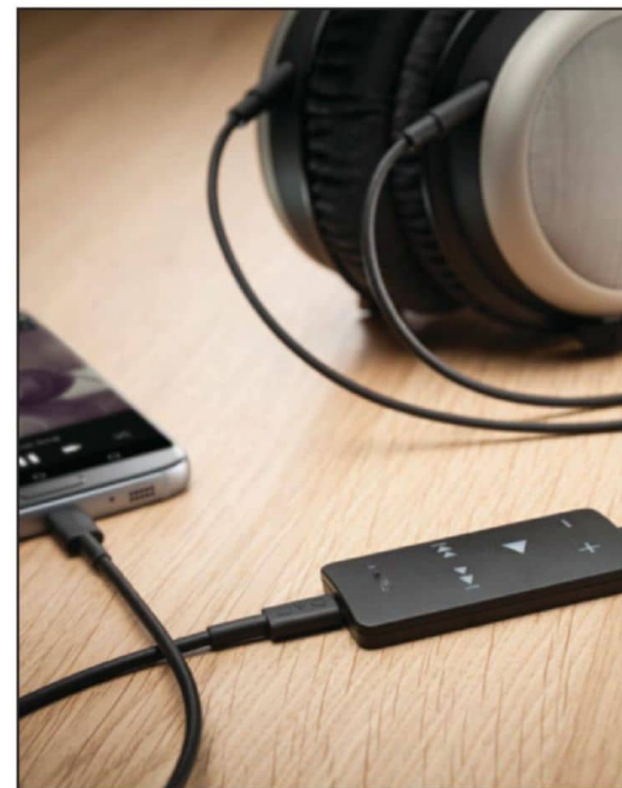
By Brian Lowe

Testing a voltage regulator with exceptionally good performance requires an even more exceptional signal source and measurement setup. In this second of a two-part article, Brian takes us through 10 years of test refinement to measure sub-microVolt ripple across a wide frequency range.

58 Measuring Super Regulators

By Jan Didden

Jan Didden, our technical editor, supplies an informative sidebar about super regulators to enhance the information provided by Brian Lowe in his main feature article.



● USB-C Market Update

14 Working with USB-C

What Audio Developers Need to Know

By J. Martins

Keep up-to-date with the new USB Type-C standard connector and the new USB Power Delivery 3.0 specification, which is complemented with a certification program for USB Fast Chargers and supported Programmable Power Supply (PPS) feature.

This article focuses on USB implementations up to USB 3.2 and brings some context to the forthcoming USB4 update.

● Departments

4 From the Editor's Desk

5 Client Index

66 Industry Calendar

● Websites

www.audioxpress.com
www.voicecoilmagazine.com
www.cc-webshop.com
www.loudspeakerindustrysourcebook.com
www.linuxgizmos.com

● Columns

SOUND CONTROL

8 How to Work with an Acoustical Consultant

By Richard Honeycutt

QUESTIONS & ANSWERS

42 Innovator Pushes the Envelope of Technology

An Interview with Bradley Pfeifer

By Shannon Becker

HOLLOW-STATE ELECTRONICS

60 More About Noise in Vacuum Tube Circuits

By Richard Honeycutt

COVER ART

Photo credit: Kanto YU6 Powered Speakers and SUB8 subwoofer (<https://kantoaudio.com>)

How to Work with an Acoustical Consultant

By
Richard Honeycutt
(United States)

In this article, our acoustical expert explains when to hire an acoustical consultant and the role that person should play in completing your project.

In years past, “everyone knew” that a cost-effective way to build a great recording studio was to cover the walls and/or ceilings with egg crating. I was even asked to invest as a partner in a local recording studio in the late 1970s, and upon visiting, noticed the ubiquitous egg crating applied as “everyone knew” it should be (see **Photo 1**).

Then the most famous brand of acoustical absorption ever to be promoted to consumers came out, and they molded the foam into egg-crate shapes, and “everybody knew” that all you needed to do to have an acoustically great room was to put this stuff all over it. Today, you can get 10,400,000 hits on the Google search “DIY acoustics.” Apparently “everybody knows” a lot more stuff these days!

The readers of *audioXpress* are likely better informed on acoustical matters than the general public, or even the tech crews at local auditoria, civic centers, churches, theaters, schools, and synagogues. Yet each of us has our own area(s) of expertise. Few of us would undertake to write our own legal documents, even if their financial impact is only a few hundred or perhaps a few thousand dollars. Yet, a distressing number of well-meaning, otherwise intelligent people will risk the performance of a multi-million-dollar auditorium, church, or synagogue by basing acoustical decisions on what “everybody knows” (or what the architect or organ-builder said). Acoustics is a

science and an art, and competence requires both formal training and experience. Those who have invested in the requisite preparation provide their services—for a fee—under the rubric of acoustical consultation.

You May Need an Acoustical Consultant...

There are several reasons why you would need an acoustical consultant, including:

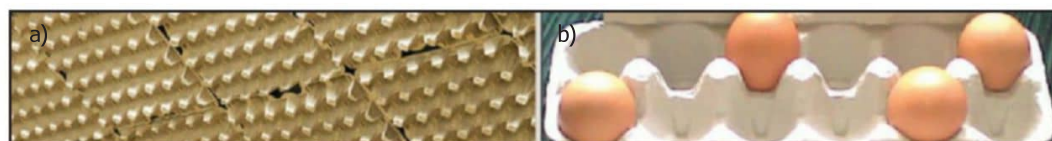
- If you are involved in the planning of a school, sanctuary, auditorium, or other venue in which people need to be able to hear music and/or to understand speech.
- If you are involved in the renovation of a facility in which people’s ability to hear and understand is important.
- If you plan to build a home recording studio, theater, or listening room.
- If at least occasionally you are responsible for operating a sound system in any venue.

In order to obtain maximum benefit from an acoustical consultant, you need to know and do certain things, which we will now discuss in a question-and-answer format, with a few real-life experiences thrown in.

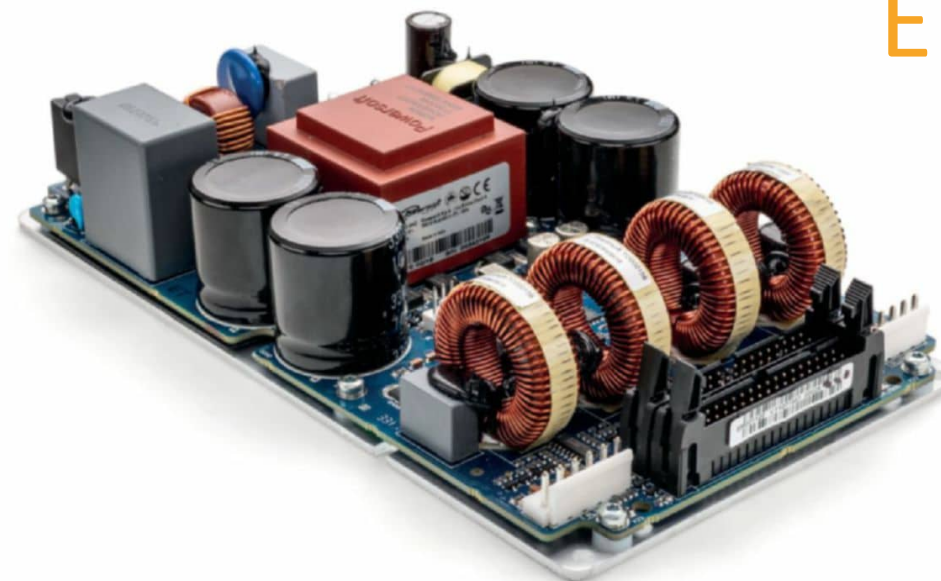
Finding a Good Consultant

The job title “consultant” is not legally regulated

Photo 1: The uses of egg crating is shown on the ceiling (a) and as it was meant to be used (b).



LITEMOD 4HC EMPOWER YOUR SPEAKER DESIGN

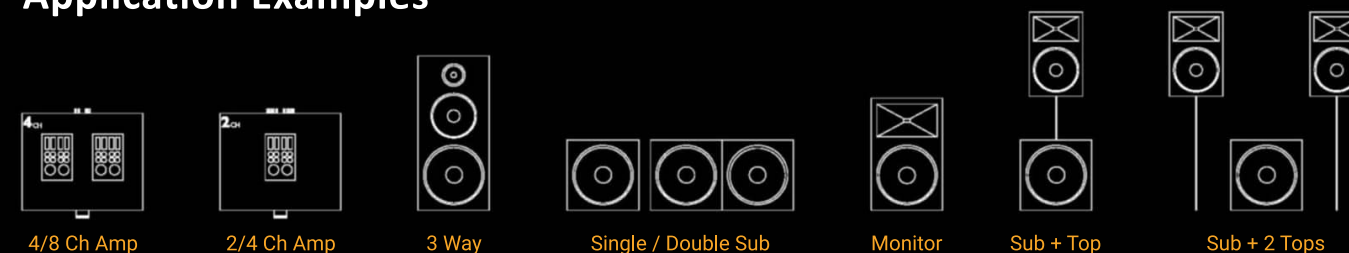


Whatever Your Applications

LiteMod 4HC is the most versatile amplification platform for high power OEM applications. Integrating PFC Power Supply and four output stages, LiteMod 4HC boosts flexibility by allowing any combination of output channel configurations. It also offers 2Ω operation capability, making it a perfect solution for a huge number of applications, from high power subs to multichannel rack amps.

- ⊙ 4 output stages (750W@4Ω each)
- ⊙ 4, 3, 2 channels, or single high power (up to 2400W@4Ω) channel configurations
- ⊙ High channel count applications
- ⊙ Universal mains PFC equipped power supply
- ⊙ Comprehensive set of protection and on-board limiters

Application Examples



What the client says	The real problem
There's a lot of feedback	There may be too much reverberation
Sounds like something is vibrating	If there's sound, something certainly is vibrating! Perhaps a mechanical buzz or rattle exists, or even an HVAC diffuser or a fluorescent ballast is making noise.
We have a lot of echo	Too much reverberation, usually
People can't hear the person talking	The talker's voice is being masked by HVAC noise, there's an echo problem, the sound system is providing poor intelligibility so they really can hear but can't understand the words, or some of the people have unmanaged hearing challenges.

Table 1: Here are a few examples that detail what a client might say and what an acoustical consultant interprets the words to mean.

in the same way that “physician” or “therapist” is. Thus, a “business consultant” may be a person who has managed a business with (hopefully) some degree of success. (S)he may be a true consultant who shares expertise with clients for a fee, or perhaps just someone who sells books and newsletters to all comers and makes after-dinner speeches. In the same way, an “acoustical consultant” may be a trained, experienced professional or a salesperson for acoustical treatments and/or sound systems. You can contact a trusted architect who can recommend a good consultant.

There are several organizations, in at least one of which true consultants are likely to hold membership. These include the Audio Engineering Society, the Acoustical Society of America, and the National Council of Acoustical Consultants in the US and some other countries. Additional organizations exist in other nations. Since expertise in acoustics, as in all other sciences, requires significant continuing education, most serious acousticians maintain membership in one or more of such professional organizations in order to keep up to date. These organizations often have member lists on their websites, from which you can get a lead to a competent consultant.

A true acoustical consultant does not sell acoustical treatment products.

Meeting with a Consultant

In your first encounter, you should expect detailed questions, since the consultant’s first task is to identify your needs. (S)he will be accustomed to hearing descriptions of acoustical goals, problems, or issues in common language, so there’s no need to try to speak in “acoustese.” Actually, trying to communicate using terms that you may not fully understand is more likely to create problems than to enhance communication.

Table 1 shows the kind of translations I often have to make when clients state their acoustical

problems in jargon they don’t fully understand.

If you simply tell the consultant that people have trouble understanding the spoken word in the venue, or the music does not sound clear, (s)he can take it from there.

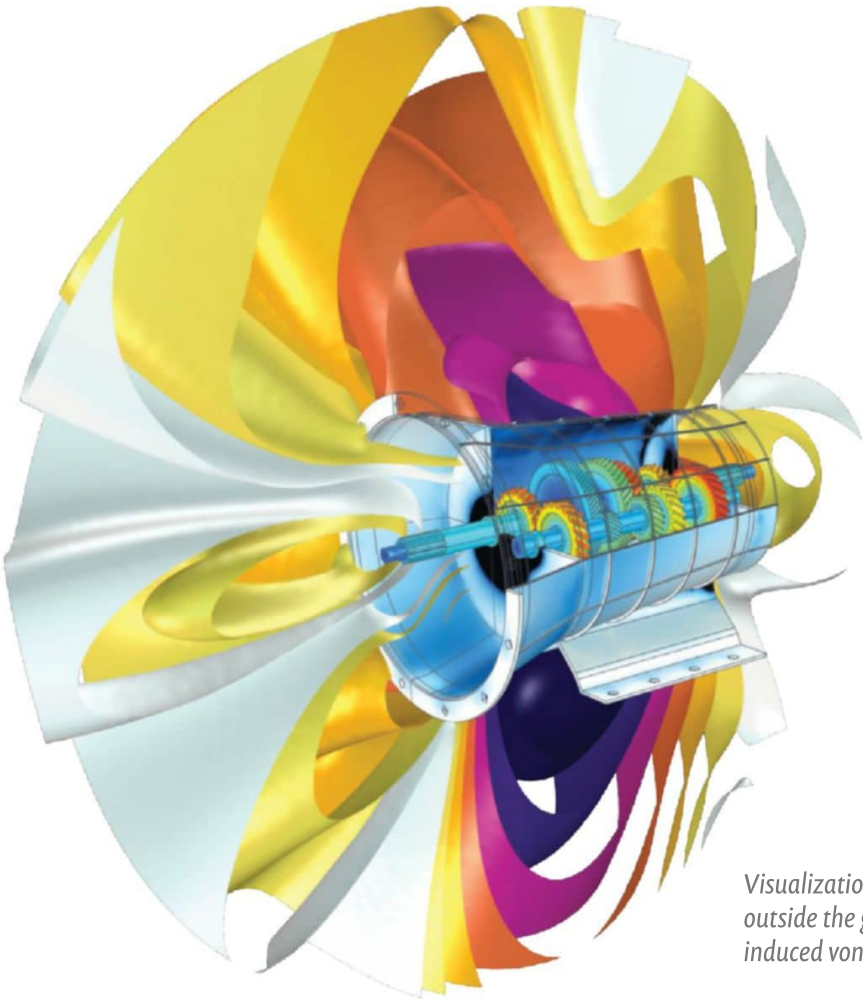
Depending upon the nature of your problem and the particular consultant, your initial contact with the consultant may result in:

- Free advice—don’t expect this, and be grateful if you get it.
- An offer to schedule a site visit, probably for a fee, which the consultant should specify. This may involve interviews with stakeholders, looking at and listening to the venue, and/or acoustical measurements.
- A referral to another professional if the consultant determines that (s)he is not the best person to help you.

In preparation for the first contact with the consultant, set your own boundaries: budget, extent of changes to the venue you are willing to consider, and the importance of acoustics relative to visual aesthetics. (If a certain proposed acoustical treatment offends the interior designer or the venue’s “pretty committee,” who wins?) Acoustics are constrained by the laws of physics. **Photo 2** shows several types of acoustically absorptive treatment. Different people will have different opinions of the appearances of each.

A visit from a certified computer repair person (with probably a couple of years’ training) may cost \$100/hour or more. An acoustical consultant’s fee (covering the consultant with probably 4-10 years education, \$10,000 to \$20,000 worth of specialized software, and another \$10,000 or more worth of measuring instruments) is a bargain if it is less than \$300 per hour. Don’t base your expectations on the cost of an electrician; the cost of a medical specialist is a more realistic comparison.

How noisy is this gearbox design?



Visualization of the noise pressure level outside the gearbox and vibration-induced von Mises stress in its housing.

Building quieter transmission systems starts with designing quieter gearboxes. Noise, vibration, and harshness (NVH) testing is an important part of the process, but you are not limited to conducting physical experiments. To improve gearbox designs well before the production stage, you can perform vibroacoustic analyses using simulation software.

The COMSOL Multiphysics® software is used for simulating designs, devices, and processes in all fields of engineering, manufacturing, and scientific research. See how you can apply it to modeling gearbox vibration and noise.

comsol.blog/NVH-simulation

Be prepared to help the consultant define the scope of work that meets your needs and budget: If you have echo and reverberation problems, noise intrusion from other rooms or from outdoors, and noisy HVAC, that's three separate projects, and your budget may require you to prioritize or to split them into phases.

If you have an architect's drawings of the venue, life will be much simpler. If not, the consultant may have to work from photos and physical measurements of the space. So if there are drawings, but you are not the "keeper" of them, it will help the process if you can find them—preferably in the form of CAD files—and have them ready for the consultant.

Be sure to let the consultant know the contact information of everybody who needs to receive copies of the recommendations that will come from the acoustical analysis.

After the Recommendations

On a major building project some years ago, the owners chose to model their new building on a plan they found in a magazine or brochure. They took the plan to a design-build firm, who told them that no architect would be needed. Then my acoustical consulting services were engaged, and I received information from the builder and the engineering firm. When I issued my recommendations, I sent them to the owner,

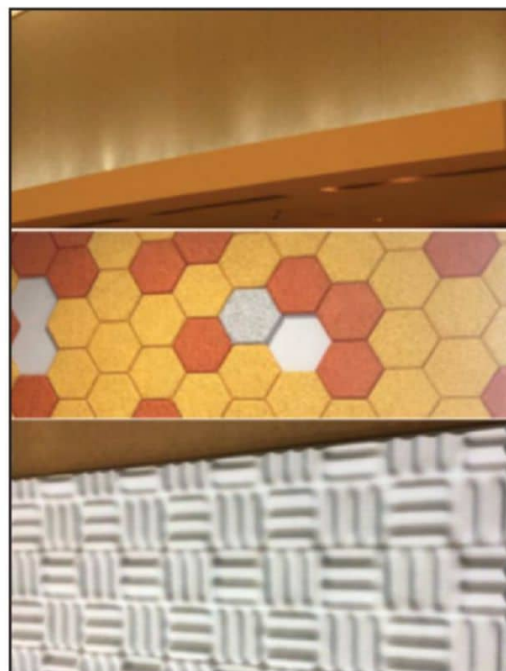


Photo 2: There are several different treatment options designed to suit different tastes.

the builder, and the electrician. (My scope of work included a sound system as well as acoustics.)

On a site visit, I decided to take a look to make sure that the various different ceiling tiles I had recommended were being installed in the correct places. It turned out that the tiles were being installed randomly. I asked the builder, and he said he had received no instructions on which kind of tile went where. (Of course, that means he had ignored my e-mailed recommendations.)

The engineer said he had read the recommendations, but thought the builder would take care of following them. (The engineer apparently did not understand that one of the jobs of an architect is to coordinate the efforts of the "trades"—electricians, carpenters, plumbers, and so forth—and make sure all the consultants' and engineers' recommendations are incorporated into the drawings from which the builder works. So if the builder and engineer claimed that no architect was needed, they should have taken responsibility for this coordination.) Although as a result of my site visit, an acoustical disaster was avoided, the bottom line is that it is essential to make sure that the consultant's recommendations are incorporated into the construction drawings.

Once the consultant's recommendations have been incorporated into the construction drawings, you should follow up to make sure they are implemented. I consulted for a church some years ago about the choir not being able to hear each other well so they had trouble keeping synchronized and in tune. After I studied the issue and made my recommendations, the Minister of Music commented, "That's pretty much what the last consultant said." I asked how many of those recommendations had been implemented, and she said, "None, as far as I know." All the best advice in the world is useless if not acted upon!

My most recent example is another facility in which I consulted on acoustical design only. As part of my analysis, I took the speaker design from the sound contractor and inserted it into my computer model of the room.

Seeing a few problems, I made comments to the contractor, who further analyzed the design and then modified it to accord with my recommendations. I submitted my report, and since the project had budgetary limitations, I recommended an acoustical treatment that performs well at a low cost, and expressed the caveat that some people do not like the appearance of this product, so if they preferred, I would suggest a different product for treatment. After the

project was completed, the owner contacted me and said they had not installed the recommended treatment, and did not like the appearance of the product I had recommended, so could I recommend something else. He also said that the occupants liked the room, but some said it was a little reverberant. Further investigation revealed that they had used different furniture (thicker upholstery) than they had told me, so the actual reverberation was not far from that for which I had designed. It also turned out that most of the occupants were pleased with the acoustics as they were, so no further changes were needed. But the owner sent a photo that included the speakers. These were not located or aimed according to either the contractor's first or revised plan.

To save money, the owner had decided to use the contractor's specifications and hire a local company to install the speakers, which they did without reference to the design upon which I had based the auralization I provided to the owner. The local company had done a pretty good job, so the end results were pretty good, even though neither the acoustical recommendations nor the



speaker mounting/aiming recommendations were followed. Although there was the potential for serious problems with this project, the owner was spared the logical consequences of his decisions.

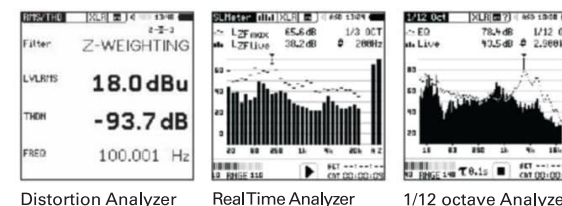
My grandmother used to say, "Heaven watches out for fools and children!" Apparently so, but in working with a consultant, please follow up to make sure the planned procedures are followed and changes are not made in mid-stream! **Photo 3** shows a large church sanctuary whose acoustical design was followed properly, with excellent results. 

Photo 3: Here is one example of a beautiful outcome, visually and sonically, that came as a result of following an acoustical consultant's advice.

Ready for any Challenge!

Discover an Audio Analyzer you can trust for your application:

- Sound Level Meter class 1
- Level RMS / THD+N
- 1/1 or 1/3 octave RTA (up to 1/12 optional)



NTi
AUDIO | NTi Audio Inc.

americas@nti-audio.com | (503) 684 7050 | www.nti-audio.com/XL2





Working with USB-C

What Audio Developers Need to Know

Every electronics designer needs to be aware of the updated USB specifications—especially due to the fact that there is a new USB Type-C standard connector and a new USB Power Delivery 3.0 specification, which is complemented with a certification program for USB Fast Chargers and supported Programmable Power Supply (PPS) feature of the updated specification. This article focuses on USB implementations up to USB 3.2 and brings some context to the forthcoming USB4 update.

By
J. Martins
(Editor-in-Chief)

In this market update, *audioXpress* shares essential knowledge regarding Universal Serial Bus (USB) technology and has compiled some recent developments from leading semiconductor vendors that need to be considered when dealing with USB implementation. The information compiled in this Market Update comes from several sources (see Resources and Sources) and includes exchanges with the USB Implementers Forum (USB-IF), including our latest interview with Jeff Ravencraft, USB-IF President & COO, Brad Saunders (Intel Corp.), USB-IF chairman, and Ismail Rahman (Intel Corp.), USB-IF CTO, audio chairman, and responsible for certification program.

The USB-IF specifications have far more details than it is possible to address here, so we highly recommend that developers follow the latest instructions and documentation provided in the USB-IF Compliance Program.

How Did We Get Here?

Back in December 2018, when I was reading those traditional end-of-the-year lists with the “best headphones you can buy” from major consumer technology websites, I couldn’t help noticing how the

“best” models in 2018 all mentioned USB-C on the “pros” side, while the “cons” specifically mentioned the use of “older Micro USB charging” as one of the reasons why 2018 models didn’t make it to the top of the list. And the reason should be obvious even to the general consumer, and especially to electronic designers. Micro USB connectors not only are highly inconvenient, but they are a standout indicator that a product doesn’t benefit from extended bandwidth features and the latest fast charging possibilities, now an essential feature for any battery-operated device.

It was in August 2014 that the USB 3.0 Promoter Group within the USB Implementers Forum (USB-IF) confirmed the updated USB Type-C specification. The specification defined the next-generation USB connector, and most importantly, established a new cable and connectivity scheme tailored to fit not only mobile and personal device product designs, but also much more efficient designs in every category, from laptops and tablets to audio DACs and recording interfaces.

The USB Type-C specification defined the physical USB Type-C cable and connector form factor along with the functional requirements for detecting and

managing USB connections and along with the new cable and connector, a new specification (USB 3.1) was announced to support USB performance at SuperSpeed USB 10 Gbps and USB Power Delivery (PD) up to 100 W. This was subsequently updated, as requirements continued to evolve with the industry needs.

But let’s focus on the connector first. USB Type-C was created because there was a need to adapt USB technology to serve newer computing platforms and devices as they trend toward smaller, thinner, and lighter form-factors. Existing USB receptacles and plugs were constricting designs given the relatively large size and internal volume constraints of the Standard-A and Standard-B versions of USB connectors, and were the main reason why the industry was using Mini and Micro USB iterations (and let’s not even mention the failed attempt with the Micro B and Micro-B SuperSpeed connectors that came with the earlier USB 3 specification...). So, when discussing inconvenience and the need for adapters and dongles, USB Type-C was designed precisely to help solve the conundrum.

Additionally, as platform usage models have evolved, it became painfully obvious that the existing set of USB connectors were not originally designed for some the usability and robustness requirements. As the USB-IF stated, “USB Type-C established a new USB connector ecosystem that addresses the evolving needs of platforms and devices while retaining all of the functional benefits of USB that form the basis for this most popular of computing device interconnects.”

Key characteristics of the USB Type-C connector design include a very robust mechanical specification with improved EMI- and RFI-mitigation, the reversible plug orientation, and cable direction (everyone understands that immediately). The USB Type-C connector also has the necessary features to also support future USB performance needs, including Power Delivery capacity. All connectors prior to USB Type-C are now deprecated and should not be implemented in new products as the primary interface.

USB Power Delivery

With the new Type-C connector, the USB 3.0 Promoter Group originally announced the release of the USB Power Delivery v2.0 and USB Billboard Device Class v1.0 specifications. Because there are two main functions in Type-C: power negotiation and alternate modes.

USB PD was designed to provide power for more devices, while still allowing data delivery and to enable flexibility in the way the direction of power is delivered. Either connected device can power



USB Type-C was created because there was a need to adapt USB technology to serve new smaller, thinner, and lighter designs, using a more robust mechanical specification with improved EMI- and RFI-mitigation, reversible plug orientation, and cable direction and support new performance needs, including Power Delivery capacity.



audioXpress discussed the activities of the USB Implementers Forum (USB-IF) in the last four years. Pictured are Jeff Ravencraft, USB-IF President & COO, Brad Saunders (Intel Corp.), USB-IF chairman, and Ismail Rahman (Intel Corp.), USB-IF CTO, audio chairman and in charge of the certification program.

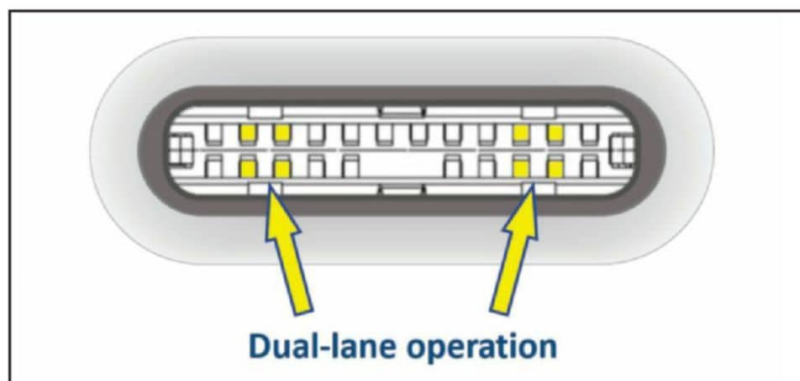


The USB connector family with examples of USB Type A, USB Type B, Mini-USB, Micro-B, and USB Type-C

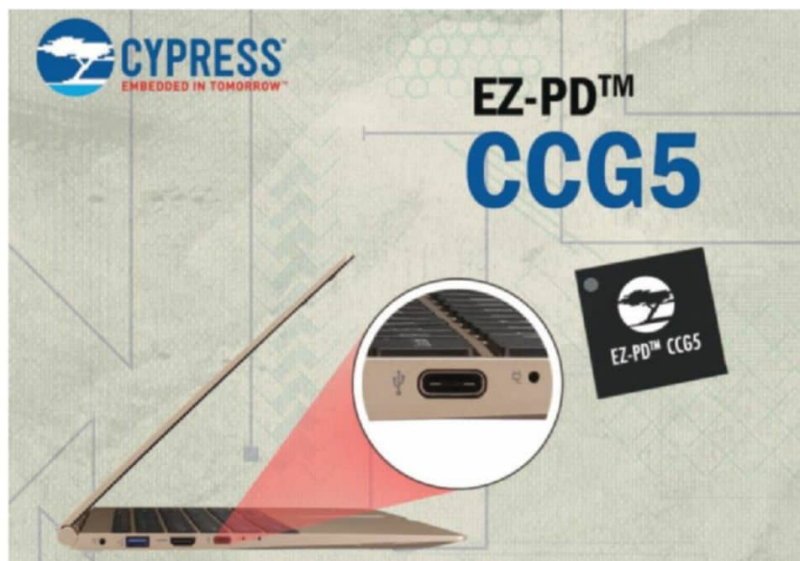
the other one, depending on configuration. Also, this includes the ability to negotiate the amount of power required by any connected device. The Power Delivery Specification also enables alternate modes to be defined and negotiated. This provides the ability to reconfigure some of the USB Type-C connector pins, allowing different applications.

The Billboard Device Class specification outlines the methods used to communicate the Alternate Modes supported by the Device Container to a host system. This includes string descriptors that can be used to provide support details in a human-readable format.

The USB PD specification also defined standardized features that support the global



Dual-lane operation on USB Type-C enables doubling the bandwidth performance for demanding applications, without sacrificing cable length with same signaling rates (5 Gbps/10 Gbps) and encoding using existing cables.



Since mid 2017, Cypress Semiconductor offers a family of USB-C controllers with Power Delivery (PD). The company offered the world's first programmable USB-C controller. The EZ-PD CCG5 controller was the industry's first two-port USB-C controller also with Thunderbolt 3 (Alpine Ridge) controllers. The EZ-PD portfolio was the first to support the latest USB PD 3.0 specification, and includes automotive-grade certified solutions.

adoption of interoperable power supplies, helping to reduce electronic waste and increase re-usability of adapters and chargers for consumer electronics—a consideration that obviously should be on the mind of every manufacturer. In July 2016, the International Electrotechnical Commission (IEC) formally adopted these updated specifications, citing “the ultimate goals of increasing external power supply re-usability, supporting consumer convenience, maintaining product reliability and safety, and providing for future technology innovations.”

The USB Type-C specification also defined Functional Extensions that enable USB Type-C hosts and devices to support optional capabilities, including Alternate Modes, allowing other standards organizations to adopt the USB Type-C cable and connector and provide additional features. Those Alternate Modes should support both the USB Power Delivery v2.0 and the USB Billboard Device Class v1.0 specifications.

Besides being designed to support USB Type-C, the USB PD v2.0 specification updated the USB Power Delivery v1.0 specification to meet the requirements of Alternate Modes with Structured Vendor Defined Messages (Structured VDMs) to discover, configure, and enter/exit Alternate Modes. This also allowed those standards organizations to create different cable/pin structures, which paved the way for the market potentially being flooded with use-specific USB Type-C cables, which not being incompatible, will minimally expose a USB 2.0 Billboard interface powered by V_{BUS} , as the specification mandates, avoiding confusing consumers.

Also, as experience demonstrated, it could result in the creation of non-supported charging modes. In 2016, it was obvious that this could completely disrupt the well-intended efforts of the USB-IF, with the industry demonstrating several different Alternate Modes, from HDMI to Mobile High-Definition Link (MHL), and DisplayPort, with the most visible effort obviously being Thunderbolt 3.

Needed Evolution

In our Standards Review article series, *audioXpress* published a two-part feature about USB 3.1 (Gen 2), USB Type-C, and Thunderbolt 3 technologies. These two articles were originally published in *audioXpress*, December 2016 and January 2017 and are now available freely online (see Resources). We will just mention that both the USB and the Thunderbolt efforts are led in big part with contribution from Intel and that, in 2015 when Intel unveiled Thunderbolt 3, it became obvious that this was something intended for professional and media creation requirements. Thunderbolt 3 introduced

Whatever your testing challenge, GRAS has the right acoustic sensor for your audio application.

Only GRAS offers a complete line of high-performance, test microphones and related products ideal for use in consumer audio and electronics applications.

As the leading global provider of microphones, GRAS has a long tradition of working with audio engineers to ensure accurate data is captured, each and every time.

Microphones from GRAS are designed for the high quality, durability and reliability that our customers demand.

Contact GRAS today for a free evaluation of the perfect GRAS microphone for your application.



GRAS

Acoustic Sensors

- Measurement microphone sets
- Microphone cartridges
- Preamplifiers
- Low-noise sensors
- High resolution ear simulators
- Head & torso simulators
- Test fixtures
- Custom designed microphones
- Speech intelligibility
- THD
- Frequency response
- Calibration systems and services



P: 800.579.GRAS
E: sales@gras.us

www.gras.us



Among the first companies to offer USB Power Delivery solutions, Renesas currently offers support for both USB Power Delivery Rev. 3.0 (USB PD 3.0) and USB Type-C Authentication.

support for USB devices to its original specification, but also replaced the original mini-DisplayPort connector being used for Thunderbolt (designed by Apple) for the USB Type-C connector (which also received significant contributions from Apple, based on its existing Lightning reversible connector). Thunderbolt 3 brought Thunderbolt to USB-C at 40 Gbps—double the speed of the previous generation—with support for USB 3.1 at 10 Gbps (at the time of introduction), and DisplayPort 1.2 (which supports 4K and 5K displays) and much more, while supplying power in the same cable.



With all the semiconductor manufacturers focusing their attention on USB Type-C solutions, in 2017, Diodes introduced a critical solution for USB Type-C and PD 3.0 implementation in all sorts of devices. Diodes introduced the DPS1133, a single-channel high-voltage power switch that was the world's first designed to meet all the demanding protection and fast-role swap requirements of USB Type-C ports.

In April 2016, the USB-IF announced the USB Type-C Authentication specification, defining a protocol for host systems to confirm the authenticity of a USB device or USB charger at the moment a wired connection is made—before inappropriate power or data can be transferred. This empowers host systems to protect against non-compliant USB chargers and to mitigate risks from maliciously embedded hardware or software in USB devices attempting to exploit a USB connection. As the USB-IF detailed, the new USB Type-C Authentication protocol equipped OEMs with “the proper tools to defend against ‘bad’ USB cables, devices, and non-compliant USB Chargers.”

Later, this would lead to the release of the USB Power Delivery 3.0 specification update, introducing developer-specific updates, and incremental features that include enabling authentication message exchange over the USB PD communications channel for standard USB Type-C to USB Type-C cables.

USB Power Delivery 3.0 supports delivery of power up to 100 W through a single cable, makes it possible to simultaneously power multiple devices, eliminating the need for a dedicated AC adapter for each device, supports Fast Role Swap (FRS) to allow devices to switch roles as power providers and power consumers, and introduced Programmable Power Supply (PPS) to make it possible for rapid charging without generating excessive heat. Also, a new USB Type-C Bridging specification provided the necessary method for bridging messages to and from a USB PD link over the USB data bus, and enabled a USB host to communicate with the USB PD interface of a downstream port in a connected USB hub, among other capabilities.

Even with all the work being done, in 2016 it was clear that the standard would need further consolidation and, in August of that year, the USB-IF announced a Certified USB Charger Compliance and Logo Program, in an effort to guide the consumer. As more products adopted the USB Type-C connector and USB PD, the need was felt to assure Certified USB chargers would be convenient and safe, making it easier to share device chargers across compliant USB Type-C products. In that announcement, the USB-IF stated: “Non-compliant chargers, whether USB or otherwise, pose a risk to the functionality and interoperability of electronics. USB-IF compliance means that products have met the highest standards in the industry, were certified to be compliant to the specification and have been tested for interoperability with other USB products. USB certification is one step toward OEMs developing great products; however, it is not a substitute or replacement for local, state, federal or international safety regulations or agencies. Companies are reminded to allocate the necessary

resources to build compliant products and submit them for testing by the USB-IF Compliance Program to achieve USB-IF certification.”

The Pains of Adoption

Thanks to all the updates meeting key market requirements, the USB-C standard started to gain rapid support with top-tier electronics manufacturers. Particularly in the mobile industry, it became clear that USB Type-C was the new standard, and semiconductor companies all offered a full range of components and solutions to support the developments. As an example, in 2016, Synopsys offered a full IP suite for SoC implementation and was shipping its DesignWare USB 3.1 Type-C Controllers compliant with the USB 3.1 specification.

In June 2016, Silicon Labs introduced a comprehensive reference design for developing cables and cable adapters based on the USB Type-C specification using its ultra-low-power EFM8 microcontrollers (MCUs), certified USB PD protocol stacks, and USB Billboard Device source code. At the end of 2016, both Microchip, Fairchild (ON Semiconductor), and Texas Instruments offered a full range of controllers and implementation solutions for USB 3.1 10 Gbps, USB Type-C and Power Delivery 3.0.

In early 2017, Cypress launched its EZ-PD portfolio of USB-C controllers, which included the world's first two-port USB-C solution, devices with support for the USB Power Delivery 3.0 specification, and devices AEC-Q100 certified for automotive-grade performance, enabling fast charging of portable electronics in vehicles. Renesas was another important vendor to offer a full set of Power Delivery 3.0 solutions, as well as USB 3.0 SuperSpeed (5 Gbps) controllers since 2017.

In January 2018, the USB-IF announced that it was expanding its Certified USB Charger Compliance and Logo Program to include Certified USB Fast Chargers, which was quickly becoming a highly demanded feature, with more than 100 certified solutions in the first month alone. Certified USB Fast Chargers support the PPS feature of the USB Power Delivery 3.0 specification, but require new USB hosts, devices, and chargers supporting PPS, for users to take full advantage of the new feature. Benefits include allowing the smartphone OEMs to better manage the thermals while charging, since adapters can allow devices to control the adapter's output voltage using the PPS mode. The device requests a PPS voltage and operating current within one of the defined ranges, makes requests as often as needed to maintain the charging profile at the battery, and charger also supports current limiting adaptive mode.

As always, they are also backward compatible with

devices that support USB Type-C and USB PD. As Jeff Ravencraft, USB-IF President and COO then explained, to remove “the guesswork out of buying a compliant USB charger.”

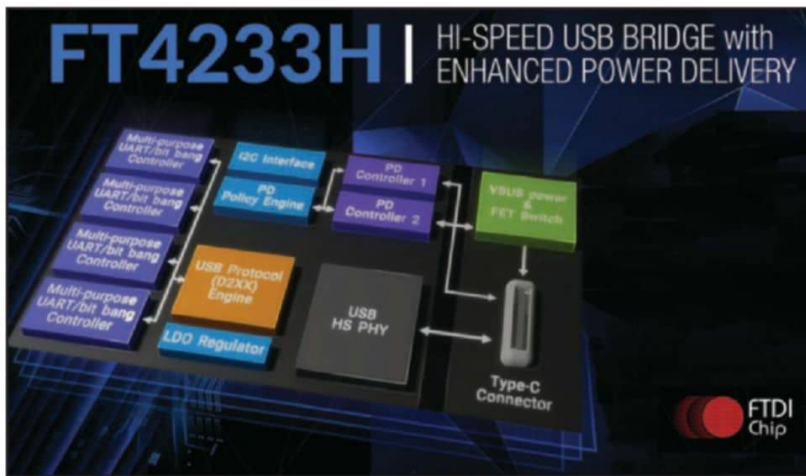
The USB-IF expanded USB Charging Initiative allows cross-vendor interoperability, allowing for the development of vendor neutral Type-C chargers, and defines an open standard that enables OEMs to save R&D, manufacturing and inventory management costs. What is new is that it introduces continued commitment to support common charging of smartphones and beyond. An example of that level of support is the Digital Europe memorandum of understanding regarding common chargers based on USB Type-C. And this adds to list of recent industry



beyerdynamic has developed the Impacto essential hi-res digital-to-analog converter (DAC), which connects directly to all types of USB host or “USB On-The-Go” interfaces, in order to enable the best possible playback quality from portable devices such as notebooks or smartphones. The Mobile Reference DAC features a ESS Sabre32 System-On-a Chip (SoC) that is able to decrypt high-resolution audio signals up to a resolution of 32 bits and 384 kHz, and even supports Direct Stream Digital (DSD) signals of up to 5.6 MHz (a). It ships with an assortment of cables, including USB Type-C and Apple Lightning (b).



Affordable home-studio USB-C audio and MIDI interfaces are now available. With eight inputs, four outputs, high-quality microphone preamps, the new M-Audio M-Track 8X4M is an example of a very nice studio-quality audio interface using a high-speed USB-C 10 Gbps connection with USB/Direct control for zero latency and 24-bit/192 kHz audio support, for only \$299 retail.



FTDI Chip is shipping its FT4233H advanced bridge IC solution with USB Type-C connectivity and USB Power Delivery Rev. 3.0 controller capabilities—supporting applications up to 100 W. With this new chip, the company has introduced the USB power delivery technology necessary to go beyond the powering of consumer electronics products and support the elevated current levels required by larger items of electronic equipment.

ON Semiconductor is shipping two devices that can be used together in USB-C (Type-C) applications. The new devices are the FSA4480, a USB Type-C analog audio switch with integrated protection, and the NCS21x series of current sense amplifiers—ideal for applications such as media players.



support for USB Type-C and USB PD by the China Communications Standards Association (CCSA) and the IEC.

“A major tenet of USB-IF is listening to developers and OEMs that are adopting our specs in real-time and then using their feedback to shape revisions or new initiatives to meet industry needs,” stated Ismail Rahman, USB-IF CTO. “Certified USB Fast Chargers are a direct result of this process. We wanted to help accommodate international regulations that require better energy management and to add a feature benefit that is passed directly to the user.”

Sometimes it’s hard to understand how complex an effort to standardize technologies like these can be. Charging mobile devices is not something consumers fully understand and they are faced with advertising of Wireless Charging, Fast Charging, and Rapid Charging. Consumers are not aware that some manufacturers are using proprietary methodologies. They also don’t necessary understand that a Qi Wireless charging pad needs to be plugged in to something and most often it will use USB Type-C. In cars, wireless charging makes sense for the driver, while all other passengers want to be able to charge and interact with their devices at the same time, so they need to plug in. When using a Fast Charger, essentially people want to plug in and know that they are going to get 60% to 80% charge in little more than 10 minutes.

As Brad Saunders, USB-IF chairman, explains, USB Fast Charging is an open standard. “If you are a developer and a manufacturer, it’s free, it’s not proprietary, and it will be interoperable. The difference is that someone doing a USB product with Fast Charging has to implement the Programmable Power Supply (PPS) feature of the USB Power Delivery 3.0 spec. Every major phone manufacturer, OEM, and silicon technology vendor are all part of our workgroup and they are all intimately familiar with the stuff. Yes, some made business decisions to do things differently in the past, but they are now fully prepared to go standard. And this is also going to be lower cost, because as volume drives up, price comes down.”

“This allows using the same chargers with any device, and get the same Fast Charging experience. Different phones and devices using different battery chemistry and implementations can actually change the levels at which they charge. With USB Fast Charging, we are not only making it interoperable today, we are also future-proofing the whole solution. When manufacturers move away from lithium-ion batteries to something else, these chargers will be able to work. Because they are already programmed to be able to change voltages and currents in a flexible way,” Rahman highlights.

Certification and Authentication

Of course, all this means that companies have to allocate the necessary resources to build compliant products and submit them for testing by the USB-IF Compliance Program to achieve USB-IF certification. The USB-IF supplies all the guidance needed for manufacturers to go through the process. An extremely valuable document is the USB-C Product Matrix, which is continuously updated. The Compliance Program uses multiple test specifications along with a Test ID (TID) to track and define the test criteria used to evaluate a product. The USB-C Test Matrix describes the mandatory test requirements for each new USB-C Product classification. The mandatory tests for each product is the union of the tests required for every product type the product implements. Products that pass this level of acceptability are considered USB-IF certified and are added to the Integrator’s List and have the right to license the USB-IF logos.

There are five avenues for certifying a product with the USB-IF, such as participating in a USB-IF Sponsored Compliance Workshop or USB-IF Platform Interoperability Lab (companies need to be USB-IF Members), attend an Authorized Independent Test Lab, participate in the USB-IF Qualification by Similarity Program, or work with OEM Arrangements. This last avenue means that a company is purchasing and reselling under its own brand, a product that is already on the Integrator’s List under its supplier’s company name. That supplier can in turn submit an online confirmation of product identity to have the products added to the Integrator’s List under the new company’s name without retesting. After the purchaser company submits the required USB-IF Trademark License Agreement it may use a USB logo in conjunction with the new products.

But there is another possible step that was added in January 2019. The USB-IF launched its USB Type-C Authentication Program, defining a cryptographic-based authentication for USB Type-C chargers and devices. This is an optional security protocol that allows USB Type-C OEMs to protect their products against harmful power surges from non-compliant USB devices and for host systems to mitigate risks from malicious firmware/hardware in USB devices attempting to exploit a USB connection.

Using this protocol, host systems can confirm the authenticity of a USB device, USB cable, or USB charger, including such product aspects as the capabilities and certification status. The authentication confirmation occurs over either USB data bus or USB PD communications channels. All of this happens at the moment a connection is made—before inappropriate power or data can be transferred. Utah-based DigiCert



Already in 2019, ESS Technology has announced a series of USB low-power audiophile CODECs that feature QUAD DAC technology, intended for use in high-quality headsets and audio adaptors, with support for high-resolution audio and an ideal platform for USB-C audio products.

was selected by the USB-IF to manage registration and certificate authority services for the USB Type-C Authentication program.

A practical usage example is for travelers concerned about charging their phones at public terminals. The phones they are using can implement a policy only allowing charge from certified USB chargers. A company, tasked with protecting corporate assets, can set a policy in its PCs granting access only to verified USB storage devices.

The USB-IF expects USB Authentication adoption to ramp up in 2019, as Ravenscraft explained. “This is an optional security protocol. We picked DigiCert to issue a root certificate to a cable or charger, or any device including a host. For any host system it’s just software,



At the end of 2018, Swiss-connectivity specialist Neutrik AG decided to launch the new mediaCON USB Type-C series of connectors for professional applications, featuring a push/pull lockable and space-saving mediaCON chassis, which can be mounted from the rear and front side. Neutrik decided to create the new mediaCON USB Type-C series, leveraging all the possibilities of the reversible connector and USB specifications, and creating a solution that is transparent in terms of data and power delivery applications when using the Type-C connector.

Resources

M. Christiansen, “Understanding USB 3.2 and Type-C,” Synopsys Tech Forum, www.techdesignforums.com/practice/technique/understanding-usb-3-2-and-type-c

M. Christiansen, “USB 3.2: The Latest USB Type-C Challenge for SoC Designers,” White Paper, Synopsys, www.chipestimate.com/partner_docs/USB_Type-C_Challenge_for_SoC_Designers_WP.PDF

C. Mayes-Wright, “System Science #1: Connection Methods: USB, PCIe, Thunderbolt or Ethernet?,” Focusrite // Spectrum, September 2017, <https://medium.com/focusrite-spectrum/system-science-1-connection-methods-2700f7a82d70>

J. Martins, “USB 3, Type-C, and Thunderbolt 3 (Part 1): An Introduction to the Latest Interfaces,” *audioXpress*, December 2016.

J. Martins, “USB 3, Type-C, and Thunderbolt 3 (Part 2): Implications on Audio,” *audioXpress*, January 2017, www.audioxpress.com/article/standards-review-usb-3-type-c-and-thunderbolt-3-interfaces-and-implications-on-audio

so there's minimal change. And root certificate is issued per company. USB Type-C Authentication is an important contribution to enable a thriving ecosystem of compliant, interoperable products."

The Latest Updates

In 2019, the USB-IF continues its work to adapt the USB specifications to the market requirements—



Jeff Ravencraft, USB-IF President and COO, and Eric Huang, Senior Product Marketing Manager, Synopsys, discuss USB Type-C market and technology developments at the Intel Developer Forum 2016. Since March 2019, Synopsys VIP and source code test suite for USB4 are available, joining the verification IP and source code test suites for USB up to 3.2, Power Delivery up to 3.0, and Subsystem Verification Solution for Type-C.



An example of a Qi Wireless charging pad, which is plugged-in to a USB Type-C cable and charger. While many consumers will be attracted by the convenience of wireless charging in some situations, USB Fast Chargers will increasingly offer a better experience providing a 50% charge in just a few minutes.

sometimes reacting to things that are only possible to envisage when actual products are starting to ship. As Rahman explains, "we really want people to adopt what we are doing. Because it doesn't just apply to USB. People are now picking up all that happened for the last two/three years. 3.5 mm headphone jack removal from most smartphones has many benefits (e.g., larger batteries and thinner devices), but it has made simultaneous audio and charging a challenge. So we had to update the audio specification to properly build charge-through USB Type-C digital audio products, defining a method for charging a device while also using Type-C based headphones. This enables developers to build lower-cost audio docks, active phone cases and low-end detachable devices. It also ensures interoperability with device vendors who implement the updated specification."

"Some people were trying to do that themselves, using proprietary methods, which is a problem, so we decided we should standardize the Type-C specification to do charging, and at the same time be used for audio. And it's not only audio, it's USB 2 or 3 data and audio."

The other focus is active cables. As Saunders explains, "Everything that we certify today are passive copper cables but we are working on an active cable spec, that would obviously give us the capability to go farther—up to 5 meters. Work is ongoing to allow cables longer than 5 meters and the updated spec introduces optical isolated active cables with length determined by USB 3.2 timing. Nominally, up to 25 meters for USB at 5 Gbps, up to 50 meters for USB at 10 Gbps. But again, whether it's electronics on a copper cable or optical, at distance we are not going to be able to deliver power. One would argue that the general consumer is never going to use a 25-meter cable, but we understand that there are niche areas that would want those longer cables."

But as Rahman explains, there is more work undergoing, including a future update to the USB Audio Device Class 3.0 Specification focusing on lower latency and synchronization issues, and addressing digital audio applications that require different serial intervals. "The updates are just to improve it. I think what we have right now is just a very good solution. All Android phones and Windows computers support it. And iOS supports it as well. It's supported across the board. The only question is that some people are interested in doing cheaper alternatives of audio."

The hurdle as the USB audio chairman knows too well is the fact that the benefits for very simple designs (e.g., headsets) is minimal, and even when adding things such as ANC to the equation, leading manufacturers still prefer to develop their own dedicated chips. Still, there's no reason not to adopt USB 3.2, which still supports 2.0 and still allows

reducing the amount of power being drawn on the host side. As we've learned, the USB-IF did all sorts of comparison tests with actual products to compare the low-power advantages and they could reach 35 hours of continuous music listening with USB Type-C usage—versus 40 hours for a device connected simply via 3.5 mm jack—on a single charge. Of course, with ANC processing on a digital headset those gains become much more relevant and the new USB Audio Device Class 3.0 Specification is certainly a useful tool for manufacturers that are willing to commit the development effort.

But for now, the focus apparently is the use of Type-C for charging with audio pass-through. "The first thing is to get everyone to start implementing digital audio. That's number one," explains Rahman. "And since we only have one connector, we want people to use the right kind of adapters so they can do both charging and listening to audio."

Saunders explains: "It doesn't have to look like a clumsy adaptor. It can be a connector with another Type-C on the side, so you can connect any charger on the side and it just works. It can look much nicer, and you couldn't do it on the old USB. One of the key features is that with Type-C we have two power supply sources and Vbus can now do 5 V, 9 V, or 20 V, whatever. The charge-through function is independent. The whole spec describes how to do that. That's on the update that is already published."

"Going forward, headsets will have to become digital. We have been testing those possibilities, Type-C, Power Delivery, USB 3.2, to provide the plumbing for developers to try things like Active Noise Cancellation, and we give them the ability to go low power, etc. Eventually putting together solutions that use all of these things and make good products out of them. Developers are trying those right now. They are trying different things, and finally someone is going to realize this is it! And everyone will start making the same," Rahman concludes.

USB 3.2 Is Now

So, at this stage many readers might be thinking, where are we at now and what should we be looking at for development? As the USB-IF explains, the USB 3.2 specification replaces all the 3.x specs that came before. Everything we have been addressing so far is updated and incorporated into one specification that is USB 3.2. The other specifications have been deprecated.

The USB 3.2 specification enables SuperSpeed USB to fully use USB Type-C cable plug/wires. It doubles the performance with dual-lane operation and uses the same signaling rates (5/10 Gbps) and encoding allowing the use of existing cables. The main benefit is to have much higher bandwidth for USB storage

and demanding applications like multitrack high-resolution digital audio streaming without sacrificing cable length. The existing SuperSpeed USB 5 Gbps cables now provide 10 Gbps of bandwidth—no need to use shorter cables.



A vast set of protocol analyzers and compliance test systems are available for USB 3.2, Power Delivery, and USB Type-C from companies such as Keysight, Ellisys, Granite River Labs, and Teledyne LeCroy. Pictured above is the Teledyne LeCroy Voyager M4x Protocol Analyzer platform for testing next-generation USB4 and Thunderbolt 3 systems.



Not all industry segments move at the same speed. In February 2019, Microchip Technology launched an automotive-qualified USB 3.1 Gen1 SmartHub IC to support the rising adoption of USB Type-C in the smartphone market and enable universal connectivity in vehicles.



Renesas Electronics recently announced two new reference designs that simplify and speed the development of USB Power Delivery (PD3.0) and USB-C battery charging applications. The RTK-251-1PowerBank3 and RTK-251-BuckBoostConverter2 are USB-IF PD3.0 certified design kits, and represent the first in a new series of reference designs for applications implementing the USB Type-C power and data connection standard.



Cypress Semiconductor recently announced the availability of a highly-integrated, automotive-qualified USB-C controller with USB Power Delivery (PD) that enables fast charging of portable electronics in vehicles. The EZ-PD CCG3PA controller provides support for the USB PD 3.0 standard with programmable power supply (PPS), Qualcomm's Quick Charge (QC) 4.0 protocol, and legacy charging standards. As the standards continue to evolve, compliance and interoperability pose an ongoing challenge, but the programmable controller overcomes these issues with its firmware upgradeability.



At CES 2019, the USB-IF demonstrated new useful possibilities such as Fast Role Swap (FRS), allowing all the USB devices to keep working even when swapping from an adaptor to battery mode—including an HDMI monitor in Alt mode.

Where to Go for Interoperability and Certification?

The USB Platform Interoperability Lab (PIL, www.usb.org/pil) is available to assist developers with USB 3.2 product development. The lab is open for USB-IF members only. There are Authorized Independent Test Labs (www.usb.org/labs), but those are not authorized to test some of the most recent features, such as multi-port products with Programmable Power Supply (PPS) capability, Fast Role Swap (FRS), USB Authentication/Security Messages, Charge Through Ports, etc. Manufacturers seeking certification must test their products at the USB-IF PIL.

With the introduction of the dual lane, that allows for two lanes of 10 Gbps or 20 Gbps, the length of the passive cable also remains the same. What was described before as USB 3.1 gen1 and gen2, etc., now is 3.2 Gen1, which is 5 Gbps, SuperSpeed USB, 3.2 Gen 2, which is SuperSpeed USB 10 Gbps, and then there's USB 3.2 Gen2x2, and what is now SuperSpeed USB 20 Gbps data rate. Basically, it's 10 Gbps bonded together. Of course, this was always described in the developer's perspective and the USB-IF never expected the consumer to have to worry about that. As Saunders explained, "We did the focus group studies and they don't get it, they will never get it. It's not a bad thing. They don't have to get it, they just want to know that it works. And that's the promise of USB."

Well, we will have to wait for the promised USB4 specification to see if there will be a simpler way to describe the differences for consumers. But one thing is certain, when working with USB implementations, manufacturers, and developers will have to deal with all those existing flavors, which will remain on the market for a while. USB4 will most probably be targeted initially at the more demanding professional applications and certain categories of devices (e.g., computers/workstations), while the mobile industry will probably stay with USB 3.2 for some time.

Sources

Analogix, www.analogix.com
 Cadence, <https://ip.cadence.com>
 CoolGear, www.CoolGear.com
 Cypress, www.cypress.com
 Diodes, www.diodes.com
 Ellisis, www-ellisis.com
 FTDI Chip, www.ftdichip.com
 Granite River Labs, www.graniteriverlabs.com
 Intel, www.intel.com
 Microchip, www.microchip.com
 ON Semiconductor, www.onsemi.com
 PoE Texas, www.PoETexas.com
 Renesas, www.renesas.com
 Silicon Labs, www.silabs.com/usb-type-c
 Synaptics, www.synaptics.com
 Synopsis, www.synopsys.com
 Teledyne LeCroy, www.teledynelecroy.com
 Texas Instruments, www.ti.com
 Total Phase, www.totalphase.com
 USB Implementers Forum, www.usb.org

USB4 Specification Announcement

On March 4, 2019, the USB Promoter Group announced the pending release of the USB4 specification, a major update to deliver the next-generation USB architecture that complements and builds on the existing USB 3.2 and USB 2.0 architectures.

While USB 3.2 controllers are expected to become available later in 2019, the market is currently being flooded with products supporting the USB Type-C connector and the now deprecated USB 3.1 specification, and the professional market—strongly propelled by Apple—adopting Thunderbolt 3 (which uses the same Type-C connector), the USB Promoter Group apparently decided it was time to go all-in and quickly update and pair the two technologies.

The USB4 specification promises a two-lane operation using existing USB Type-C cables and up to 40 Gbps operation over 40 Gbps-certified cables, with multiple data and display protocols to efficiently share the total available bandwidth over the bus, and backward compatibility with USB 3.2, USB 2.0, and Thunderbolt 3.

While there will be consequences of this decision, namely the slower ramp-up (or not) of USB 3.2 products this year, the news that USB will be matching the 40 Gbps data rates of Thunderbolt 3 might make the roadmap for all industries much clearer and effectively propel the adoption of the technology in 2020, once all the pieces fit into place. Significantly, the announcement promises to make prices for components more affordable, considering that Intel contributed its Thunderbolt protocol specification to the USB Promoter Group, enabling other chip makers to build Thunderbolt compatible silicon, royalty-free.

As the USB Promoter Group states in the announcement, "USB4's high throughput and advanced features enable new scenarios in consumer, enterprise, and intelligent edge markets, while maintaining interoperability with existing USB and Thunderbolt 3 devices."

Nevertheless, while device and host manufacturers won't have to pay Intel any royalties for USB4, increasing the speed of mass adoption, Intel will still require certification for all Thunderbolt 3 products. And Thunderbolt compatibility is not a required part of the USB4 spec, so some manufacturers might choose not to implement it.

It's important to remember that only Thunderbolt combines PCI Express (PCIe) and DisplayPort (DP) support into two serial



Cadence Design Systems and Synopsys, both already have Verification IP (VIP) solutions in support of the recently announced USB4 standard, enabling engineers to develop standard-compliant system-on-chip (SoC) designs, completing functional verification of the design.



signals, and additionally provides DC power, all in one cable. And Thunderbolt 3 will continue to support Firewire (IEEE 1394,) besides supporting all USB specifications. Also, up to six peripherals may be supported by one connector through various topologies.

As the announcement details, the new USB4 architecture defines a method to share a single high-speed link with multiple end device types dynamically that best serves the transfer of data by type and application. As the USB Type-C connector has evolved into the role as the external display port of many host products, the USB4 specification provides the host with the ability to optimally scale allocations for display data flow. Even as the USB4 specification introduces a new underlying protocol, compatibility with existing USB 3.2, USB 2.0, and Thunderbolt 3 hosts and devices is supported; the resulting connection scales to the best mutual capability of the devices being connected.

"The primary goal of USB is to deliver the best user experience combining data, display, and power delivery over a user-friendly and robust cable and connector solution," says Brad Saunders, USB Promoter Group Chairman. "The USB4 solution specifically tailors bus operation to further enhance this experience by optimizing the blend of data and display over a single connection and enabling the further doubling of performance."

Every USB 4 device and host will also have to comply with USB Power Delivery (PD). USB PD can theoretically provide up to 100 W, but charging devices do not have to support that amount of power.

With more than 50 companies actively participating in the final stages of review of the draft specification, the USB4 specification is on track to be published around the middle of 2019. Coincident with the release of the USB4 specification, the release of an updated USB Type-C Specification will be made to comprehend USB4 bus discovery, configuration and performance requirements. The announcement also confirms that the specification update "is part of the USB performance roadmap and is specifically targeted to developers at this time. Branding and marketing guidelines will be established after the final specification is published."

Intel is promising the integration of Thunderbolt 3 into upcoming Intel processors and is working closely with Microsoft to deliver built-in Windows 10 support for Thunderbolt 3. "By collaborating with the USB Promoter Group, we're opening the doors for innovation across a wide range of devices and increasing compatibility to deliver better experiences to consumers," says Jason Ziller, General Manager, Client Connectivity Division at Intel.

Building a Null Tester Device

By
Ethan Winer
(United States)



Photo 1: The Null Tester is self-contained and compact thanks in large part to the use of surface-mounted devices (SMDs). The rear panel accepts inputs from XLR, 1/4" phone, and RCA phono plugs.

Ethan Winer details the construction and theory behind his Null Tester. The Null Tester sends the same audio signal through two paths, then it electronically subtracts one signal from the other to obtain the difference.

Over the years I've designed many audio devices including equalizers and crossovers, a distortion analyzer and other test equipment, a stereo synthesizer, and made modifications to pro audio devices, and much more. Many were published as DIY articles in a now-defunct magazine for recording professionals, and those that are still relevant are archived on my website (see Resources). But I still like to tinker, and my latest project is the Null Tester, shown in **Photo 1** and **Photo 2**. This device compares any two audio wires (plus some electronic components and other simple devices) to identify their differences. Audio quality is usually assessed by measuring the four standard parameters of frequency response, noise (including hum), distortion, and time-based errors (wow, flutter, and jitter). But some people wrongly believe there may be other properties missed in these standard tests.

How the Null Tester Works

The Null Tester avoids that potential objection by sending the same audio signal through two paths,

then it electronically subtracts one signal from the other to obtain the difference. If the signals at the other end of the wires are identical, the result is silence. In other words: $A - A = 0$. Otherwise, the remaining residual can be assessed for audibility based on its volume level and content. Note that a null test doesn't actually "measure" anything—yet it reveals all differences between two signals, including things for which you might not even be looking. One important use for the Null Tester is to compare a \$3 RCA wire to a \$1,000 RCA wire!

Irrational beliefs about "wires" are common among audiophiles, and even some famous recording professionals have claimed that spending thousands of dollars on signal wires is a worthy investment that yields an audible improvement. Such beliefs are often held by the same people who reject conventional measuring. I think there's great value in devising a way to prove that two wires really do identically pass audio, and thus, by definition must sound the same no matter what someone believes they hear. This is what the Null Tester does, and in a way that cannot be refuted.

When comparing wires, the null residual will be 60 dB or more below the input signals, depending on the wire capacitance and other factors. So the Null Tester raises the gain after nulling in 10 dB steps between 20 and 80 dB, and the output amplifier can increase that to a maximum total of 114 dB. This lets you view even smaller residuals on an external voltmeter or oscilloscope. The balance required to obtain a null down to complete silence is so critical that tiny 2 pF to 6 pF variable capacitors are needed to ensure precisely equal phase shift in both signal paths. A phase difference as small as 0.006° is enough to limit the null depth to less than -80 dB, which is at the edge of audibility with certain types of program material under the most favorable conditions.

The Device

This device might become a commercial product, and there isn't room to show the entire schematic anyway, but **Figure 1** presents the most important parts. The input circuit isn't shown, but Input 1 is a simple unity gain buffer and Input 2 is unity gain inverting, so the signals cancel near the middle of the 10-turn precision Null Control. Both input stages are DC coupled to avoid adding distortion from coupling capacitors. The first capacitor in the audio path is C7, and that's a high-quality film type, though a small amount of distortion after the null pot wouldn't be a big problem anyway. I used OPA1612 op-amps having 0.000015% distortion (yes, really) and with an input noise level of only 1.1 nV/√Hz to minimize the Null

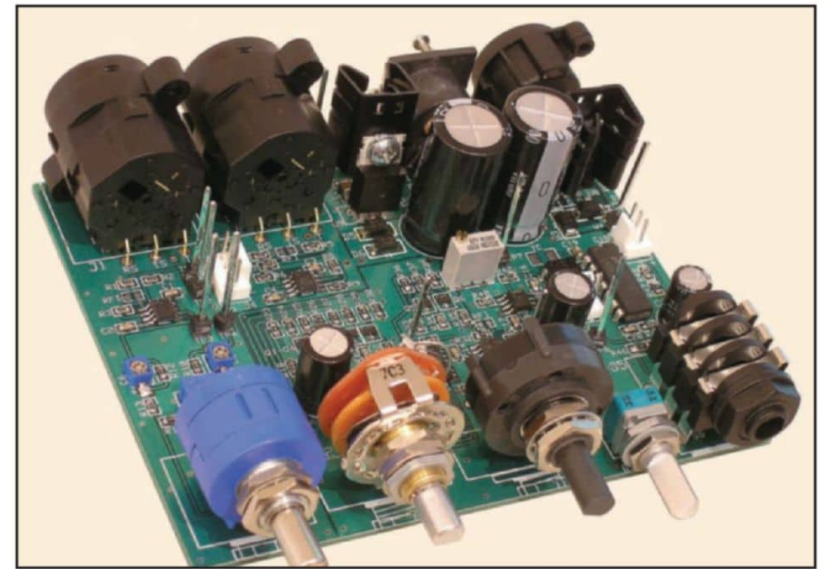


Photo 2: The circuit board includes a VU meter driver, plus a 2 W amplifier sufficient for powering headphones or a small loudspeaker.

Tester's own artifacts as much as possible. Nulling is so sensitive that even with a 200 Ω 10-turn pot—the lowest value I could easily obtain—tweaking the pot for a complete null was too coarse when combined with the 5.1 kΩ series resistors. Adding 22 Ω in parallel simulates having a much smaller value.

Figure 1 shows the digital gain-switching circuit I devised to avoid bringing the highly sensitive microvolt-level null residual off the board up to the rotary gain switch. The OR gates enable different combinations of gain spread across the two op-amp stages, with the second stage having a starting gain of 20 dB via R33. Transistor switches bring the gain resistors down to ground, and these particular transistors have an On resistance of only 35 mΩ. This greatly reduces the distortion that would occur when using normal transistors as gain switches with

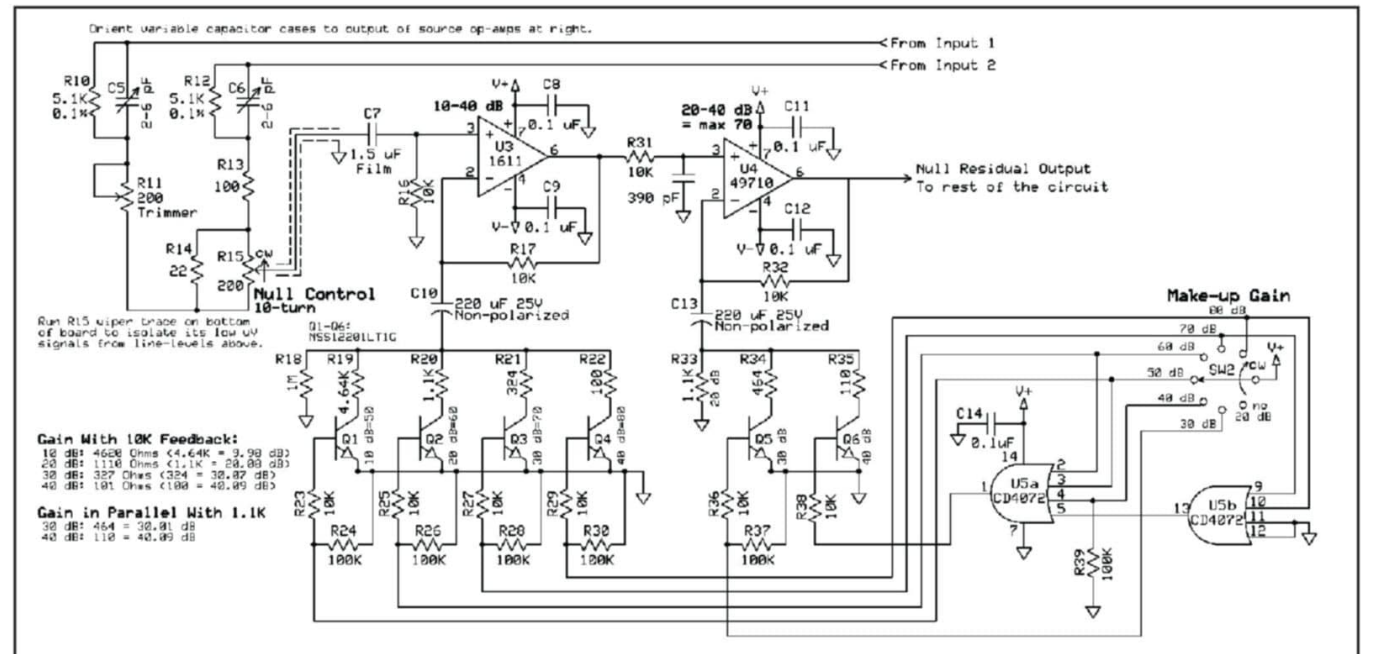


Figure 1: This schematic shows the phase compensation, nulling, and digital gain-switching sections of the Null Tester.



Photo 3: This first version of the Null Tester was a massive project that in the end was too complicated and expensive to build as a commercial product.

small signal levels, and allows using lower value gain resistors, which reduces circuit noise. These junction transistors also avoid the rising high-frequency response that could occur with field-effect transistors (FETs), because the capacitance of typical FETs yields a relatively low impedance at high frequencies compared to the gain resistors.

Two-stage amplifiers like this usually put most of the gain in the first stage to minimize circuit noise, but that wasn't practical here because the transistors would start to conduct when U4 Pin 2 gets much above one volt.

By putting the first 40 dB of gain in the second stage (U4), Pin 2—which follows Pin 3—is kept safely below one volt at all gain settings and signal levels. Having the first stage amplify the initial 20 dB to 40 dB would yield lower noise, but when the nulled residual is so large that only 40 dB or less total gain is needed, the circuit noise from a unity-gain

first stage is moot. (I use the term “circuit noise” to describe the hiss sound you hear at high gain settings, but it's more formally called thermal noise or Johnson noise after John B. Johnson who worked at Bell Labs in the 1920s.)

A four-layer PC board and surface-mount devices (SMD) reduce the board size and cost, though the 0805 SMD resistors I used are about 1/6 the size of a grain of rice! But soldering isn't difficult with the right tools, 0.025" solder, and a lighted magnifier. In fact, learning to build a device using SMD parts made this project much more interesting and fun for me. Further, many of the latest and greatest op-amps and other components are available only as SMDs. But be careful with SMD ceramic capacitors because their capacitance can reduce dramatically as the DC voltage across them rises. So you may need to buy parts that have a higher capacitance than required, based on the percentage reduction in the spec sheet under “DC Bias Characteristics” or similar wording.

I have to admit that with my 70-year-old eyes I was a little fearful about trying to populate a PC board with such small components! But a good friend showed me how she does it, and it turned out to be surprisingly easy. The key is to first tin one pad with solder, then hold the part with tweezers and tack it onto the tinned pad. It might not be a perfect connection but that doesn't matter. Then after you solder the other end of the component, you'll come back and re-flow the first side.

I designed the unit and drew the schematic using the fabulous, free program from PC board maker ExpressPCB. A companion program to design circuit boards is also free, and accommodates boards with one, two, or four layers. One great feature of these sibling programs is they share common data, making it easy to confirm that the PC board layout matches your schematic. I designed the panel labeling in Microsoft Visio, then I printed it on card stock using 3M photo mount spray glue to hold it in place. I devised this method for my Mojo Maestro DIY article, which was published in the October 2017 issue of *audioXpress*, and it works well as long as you're reasonably careful not to scratch it up.

Behind the Design

When I first thought to develop a Null Tester, I had grandiose plans to develop a serious product that could test and compare all sorts of audio devices. I used null testing in my Audio Engineering Society (AES) Audio Myths Workshop video to compare various software operations using WAV files. So it seemed only natural to develop an analog version to test audio hardware. For example, when you compare the input and output of an audio device, the null

residual will contain only the noise and distortion added by the device. You can then measure the residual level relative to the output signal, and analyze its spectrum with a software Fast Fourier Transform (FFT), or even listen to assess its audibility.

One big feature of null testing is you can use music as a source signal. Many audio enthusiasts wrongly believe that sine waves aren't good enough for testing audio gear. However, a very long time ago French mathematician Jean Baptiste Fourier (1768–1830) proved that music (and indeed all sound) is comprised entirely of sine waves. So by using music as a test signal, people suspicious of objective measuring with sine wave test tones lose an important argument!

I spent \$3,500 over two years designing and building the Null Tester shown in **Photo 3** and **Photo 4**. I thought initially it would be a commercial product that could compete with \$10,000 analyzers but sell for half the cost. So I designed a full-featured version containing a built-in multi-tone signal generator, 24 dB/octave sweepable high- and low-pass filters to exclude the frequency extremes when needed, A-Weighting, input padding to accommodate power amps up to 5,000 W, and much more. Alas, once the unit was completed I realized that even a teensy amount of phase shift precludes getting a usefully deep null. That means it wouldn't be feasible to compare preamps, or power amps, or most other common audio devices, unless complex variable phase compensation was also added. D'oh! I should have built and tested a simple breadboard version first. Fortunately, I knew that an analog null test could compare signal wires, even if nothing else, and that alone was worth doing. So I reduced the concept to that much simpler goal, and it was a success.

The Completed Tester

Once the reduced Null Tester was completed, I made a video to demonstrate the device in operation. The first part of the video explains all about null testing in detail, then the demonstration portion compares three inexpensive wires plus a \$700 “boutique” wire. I don't mind giving away the ending: All four wires were proven to pass audio identically down to a level below –110 dB. In fact, I didn't think to make this an important point in the video: The Null Tester's inherent noise floor is –110 dB, but our ears can discern the presence of music and speech as soft as 20 dB below the noise. When the Null Tester is set for the deepest null, no music can be heard at all. That means the null is actually 130 dB down, or even more, not “merely” 110 dB. I wish I had thought to make that point where I show music being nulled out completely in the video!

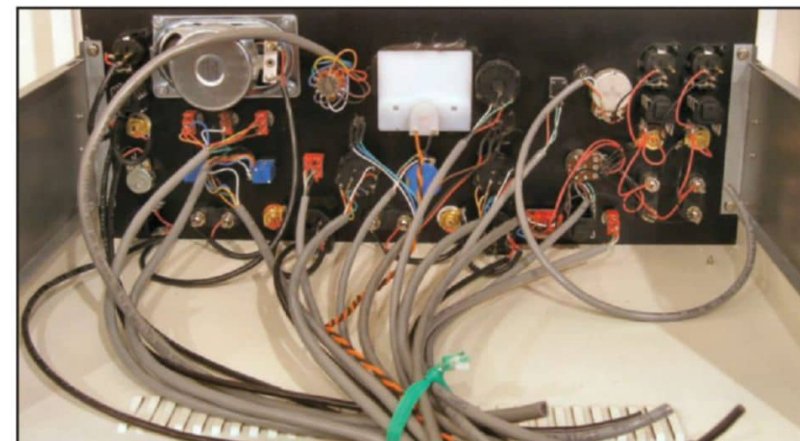


Photo 4: With so much hand wiring, it would be impossible to produce this in quantity without a major redesign to use PCB mounted controls and one or more daughter boards. It took me dozens of hours to connect all the multi-conductor wires shown here, not to mention the PC board header connectors at the other ends (yet to be attached in this photo).

Even though my grand plan to start a company selling this unique audio testing method didn't pan out, I still consider the project a success. Clearly, the tests in my video prove there are no mysterious properties of audio that engineers don't know about. They also show that human hearing perception is not as reliable as many believe, which is at least as important a point to make. Indeed, if two wires can be nulled to silence, that proves beyond all doubt they pass audio identically, no matter what you think you heard.

About the Author

Ethan Winer has been an audio engineer and professional musician for more than 45 years. His Cello Rondo music video has received nearly 2 million views on YouTube and other web sites, and his book *The Audio Expert* published by Focal Press, now in its second edition, is available at amazon.com and Ethan's own web site ethanwiner.com. Ethan is also a principal at RealTraps [http://realtraps.com], which is a US manufacturer of high-quality acoustic treatment.

Resources

E. Winer, “Ethan's Magazine Articles (and Videos),” <http://ethanwiner.com/articles.html>.

E. Winer, “Audiophoolery,” <http://ethanwiner.com/audiophoolery.html>

E. Winer, “Build the Mojo Maestro,” *audioXpress*, October 2017, www.audioxpress.com/article/you-can-diy-build-the-mojo-maestro

E. Winer, “Audio Myths Workshop,” presented at the Audio Engineering Society (AES) Convention, October 2009. www.youtube.com/watch?v=BYTIN6wjcVQ

E. Winer, “The Null Tester,” YouTube, www.youtube.com/watch?v=ZyWt3kANA3Q

ExpressPCB, <http://expresspcb.com>

A New Part Introduction for 2016

1.8 nV Low Noise Dual P-Channel JFET

4pf Low Capacitance

Complement to N-Channel LSK489

LSJ689 Series

New LSJ689 Dual P-CH JFET

- Low Noise < 1.8nV
- Low Capacitance: 4pf max
- Low Offset: 20mV max
- Complement to Dual N-Channel JFET - LSK489
- Ideal for Differential Amplifier Applications when uses with the LSK489
- Ideal for Voltage Controlled Resistor Applications
- TO71, SOIC-8, SOT23-6, ROHS Packages
- Contact the Factory or Visit the LIS Website for Data Sheets/Pricing/Samples

www.linearsystems.com 1-800-359-4023

Restoration and Revival of the McIntosh MC30 (Part 2)

Finishing the Restoration

By
Bruce Brown
(Vintage Tube Audio)

In the second part of this article, Bruce Brown discusses some important information, including the power supply rebuild and some improvements you can make to help your MC30 last another 50 years.

I want to begin by clarifying a couple of things from the first part of this article. While I concentrated on the MacKIT 30 as the guide (see **Photo 1**), there are at least four other versions. Each of them have some changes or improvements in the original design. There are differences in the preamp section, voltage amp section, the output section, and the bias power.

The power supply is the most significant. As for the rest of the tag board, you just change parts that are on the original with new and updated parts of similar value. In many MC30s, the bias voltage is supplied by a bias tap on the power transformer. This is the case with the MacKITS. On later units, the bias voltage is pulled off one of the high voltage connections on the plate of the 5U4 rectifier tube. More on this later.

Replacing the Can Cap

Now we come to the most difficult part of the whole project, replacing the can cap on the top of the chassis. This is where the Weller 100 V/140 V soldering gun comes into play. Remove the 2 W to

10 W resistors from the can cap. Remove the cloth covered wire that goes to the center tap of the output transformer and move it out of the way. Also remove the ground wires from the can. There is also a smaller red wire that runs from the 5U4 (an unused pin) to the can cap where the two 10 W resistors are connected, remove this also. There is a small red wire that runs to the tag board to power the preamp section, also move this wire out of the way. (It is really helpful to take some invisible frosted Magic cellophane tape and label each of the wires so you know where they go, as the color may have faded). In the 30s, there is a wire off the power transformer that goes to the tag board, in others, there is another small red wire that comes off the 5U4, unless you are replacing the octal socket, you can leave it connected to the 5U4 and the tag board.

The workers who built these amps really liked to wrap several turns of wire around terminals and add lots of solder, so sometimes it is difficult to get everything off the can or tag board. Take your time

and you will get it done. Again, my suture needle holder works great for unwrapping wires while the solder is hot. Once you have the stuff off, you can straighten the twist locks that don't have solder on them. I then use a pair of heavy side cutters to cut off the other lugs, you still may have to remove some of the solder with a small steel brush and rock the can back and forth until it comes free (see **Photo 2**).

A word on filter cap selection: You can use a CP C-EC80-40-30-20 from CE Distribution or an Authenticap with sections of 80 mfd 550 V, 40 mfd 550 V, 30 mfd 525 V, and 20 mfd 550 V. I have used both types and I have never had a failure with the Authenticap, while I have had a couple of failures in the first six months with the CPs. The Authenticaps are more expensive, but the reliability is extremely important to me, in my business.

Take your new can and insert it so the 40 mfd section is closest to the back panel of the amp. Use a pair of sturdy pliers and twist each can lock tab one-eighth of a turn. Now check to see if the can is straight and level.

Rewiring the Rectifier Tube Socket

At this point, we are going to rewire the rectifier tube socket. With this small change, you can use a variety of rectifier tubes, both indirectly and directed heated cathodes of the 5 V series. As the socket is originally wired, you are limited to a couple of rectifier tubes. This modification is very helpful when you finish the amp and are trying to get all the voltages to meet factory guidelines. Going from a 5U4 to a 5R4 can drop your plate voltage by 30 V. You can also fine tune it by using others such as the 5AR4, the 5Y3, and the 5Y4. More on this later.

Remove the wires (except the high voltage to pins 4 and 5 and the 5 V wires that go to pins 2 and 8) and resistors that go to the rectifier tube socket. Connect a wire between pin 8 and the 40 mfd section of the

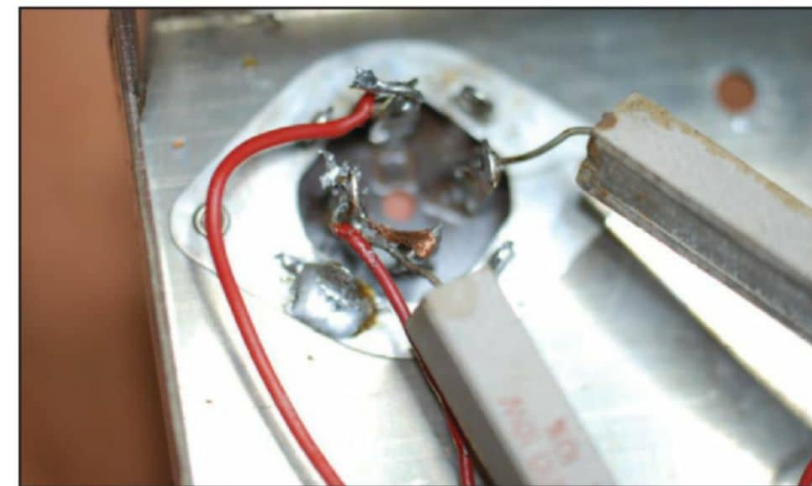


Photo 2: When removing everything off the can and tag board, you still may have to remove some of the solder with a small steel brush and rock the can back and forth until it comes free.

can. Don't solder that one yet. Connect the output transformer ground wire and the CT of the power transformer to one of the ground lugs on the can—really heat this up and flow solder until it is also attaching the lug to the metal can mount. There are two other ground wires that you removed, one goes to the tag board and the other goes to the front panel, connect these to one of the other ground lugs and flow solder the same as before. Now your can should be very stable.

Before you reconnect the power resistors, you are going to wire the rest of the can. Please refer to **Figure 1**. Connect a wire from pin 1 of the rectifier tube socket (no solder) the other end connects to the 80 mfd section of the can. (NS) Connect a wire (6" to 8" is fine) from the 80 mfd lug. Solder these two wires to the lug now. This wire you connected should run around back of chassis for the output current transformer (CT) fuse for added protection. (Please refer to the improvement section of the article.) Connect the 10 kΩ 10 W resistor. (I always replace the power resistors both for appearance and reliability.)

The lead that goes to the can should be run through the 20 mfd lug to the 30 mfd lug. Connect the small red wire that runs to the tag board to either the 20 mfd or 30 mfd lug and solder all these connections

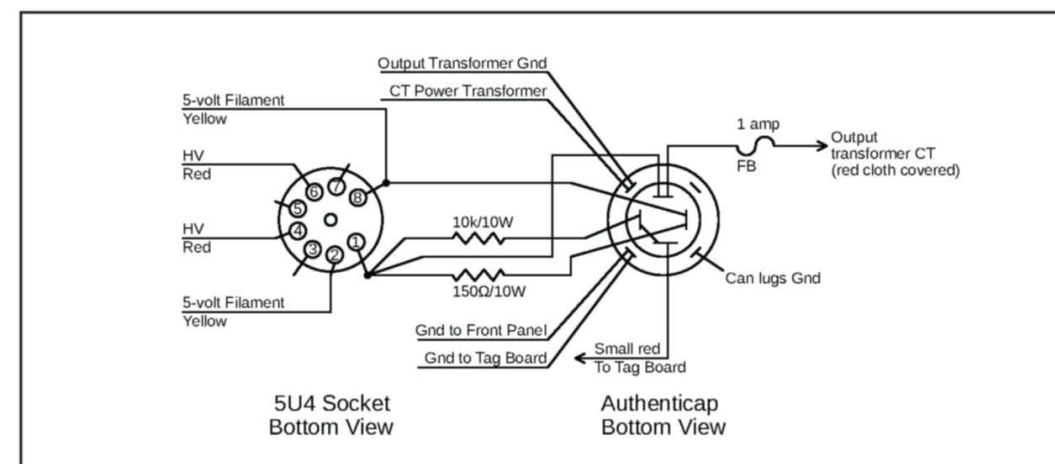


Figure 1: New capacitor wiring. Before you reconnect the power resistors, you wire the rest of the can.

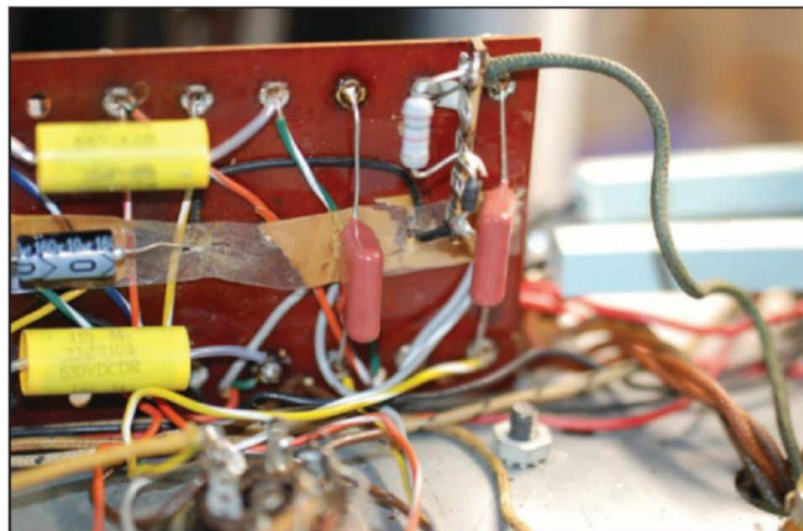


Photo 3: This is what your amp should look like before we start the fire up.

well. One lead of the 10 k Ω 10 W resistor goes to pin 1 (unused in rectifiers) of the rectifier tube. The other lead goes to the 40 mfd section of the cap. (It is a good idea to put some heat shrink on this lead.) Once you get it positioned to your satisfaction, solder the two leads to the 40 mfd section and the three leads to pin 1 of rectifier tube. All the connections to the tube socket and the can should be well soldered at this point.

Install a 500 mA to 1 A FB fuse in the high-voltage line to the output transformer. This protects the output transformer from tube failure. Since the outputs for these are extremely expensive, it is a cheap insurance policy. I often use mini fuses, but a full size is also fine. I use automotive Goop and glue the holder in a position that the CT lead from output transformer reaches one lug. Let this dry for 24 hours. The red

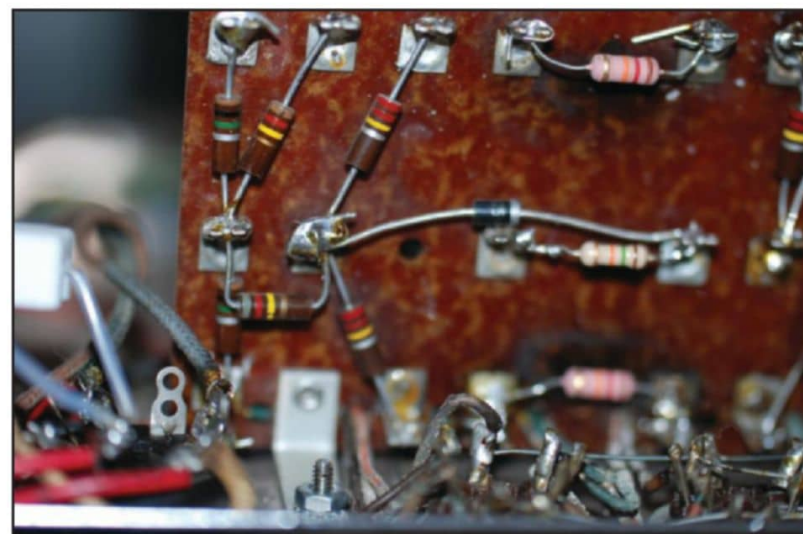


Photo 4: Another view of what your amp should look like before we start the fire up.

wire from the can cap (80 mfd) goes to the other lug. Solder wires to the fuse lugs and insert a fuse.

A couple options that I commonly do are: adding a power switch and rewiring the primary side of power transformer to the 125 V winding. Where I live, the normal line voltage is 123 V and if you use the 117 V primary winding, you will end up with excessive high voltage on the tubes. (You will also have a higher filament voltage, which is tougher on tubes than anything.) I am much happier having the high voltage less than factory specs than higher than factory specs.

Testing the Restoration

Not all MC30s have a front panel AC outlet and none of the reproduction or late model 30s have one. I **do not** drill extra holes in a chassis. A friend of mine took out one for the front panel octal sockets and put a plate in and put a switch along with a pilot light in the plate, but I just can't bring myself to do it. The choice is yours! The biggest issue with the power switch is that it involves drilling out the two rivets that hold the AC outlet on the panel. I use a long 1/8" drill bit, and very carefully remove them from the front panel. You can also use a punch on the front of the rivet to have a place to start drilling and proceed very carefully. If you use a switch get a full-size double-pull double-throw (DPDT) slide. It will fit perfectly in the outlet cutout and bolts right in. When you wire it, parallel the two sides and connect the black wire with red dashes to it (sometimes blue). This is the 125 V winding, which is usually taped up. The black and yellow (117 V) winding needs to be removed and taped up since it is not used or attached to the unused lug on the terminal strip mounted to the front panel of later 30s.

As we begin the process of final set up **please** remember, you are dealing with voltages that can be lethal! At very least, it can be quite painful! **Never** have both your hands in the chassis at the same time! The rule is one behind your back and one firmly gripping the voltage probe insulation. My dog Star likes to lay on her bed beside my bench, but during any voltage testing and set up, I lock her out of the room, for her safety as well as mine. Same goes for children.

Photo 3 and **Photo 4** show what your amp should look like before we start it up. If your MC30 has a separate bias tap on the transformer, it does not have a dropping resistor (R30) and this is why we added a terminal strip in Part 1 of the rebuild. We are going to add this resistor after we use the pot to determine the exact value. It usually ends up around 1 k Ω , but this may vary from amp to amp. Remove the resistor you had tacked on the strip. To help remember this strip, connect the leads of your 10 k Ω pot across these terminals with the resistance set at about minimum.

If your MC pulls bias off the high-voltage AC off the 5U4, this version uses a 3.3 k Ω dropping resistor before the diode. Since we have replaced the selenium diode with a silicon one, we will get much higher negative voltage if we don't adjust this resistor. This will make the amp run very cool and not produce much power. I usually clip out the 3.3 k Ω resistor and this is where I connect the 10 k Ω pot. I preset it to 3.3 k Ω or so and follow the above procedure. Adjust the pot to get in the -42 V to -45 V range at pin 5 of either 6L6. Follow the power down procedure outlined earlier and measure the value of the resistance of the pot terminals. It is usually in the 5.1 k Ω to 6 k Ω range so I typically use a 5.6 k Ω resistor.

Firing It Up

To start the fire up process, a variac is very helpful, and quite inexpensive. If you are working on a \$3,000 to \$4,000 pair of amplifiers, a couple hundred dollars for a variac is inexpensive insurance. You also must have at least one good DVM. If you have two voltmeters, it is a great time to use both of them. Connect one between the ground and pin 8 of the 5U4, connect the other one to ground and pin 5 of either of the output tubes. Bring up the voltage slowly on the variac and keep an eye on the two meters. (If you don't have two, then alternate between pin 8 of rectifier tube and pin 5 of one of the output tubes.) If at any time you are bringing up the line voltage and anything smells hot, you get smoke, or hum comes out of the speaker, immediately turn down the voltage and recheck your wiring.

Just install the 5U4 at this point. Start by inserting the 5U4 rectifier tube, and powering up the amp. Run the variac up to about 60 VAC and wait a bit. Clip the negative lead of the DVM to the chassis. Measure the voltage at pin 5 of either 6L6, you should see -30 VDC or in that range. (If it is more than -30 V don't worry.) Now check the voltage on pin 8 of the rectifier tube, then pin 1, and finally the fuse you added. You should have plus high voltage at these points. With the lead clipped to the fuse lug bring the variac AC up to about 100 V.

As the 5U4 fully warms you should see 300 V to 400 V or so. Now go back to the bias cap negative terminal and see where that voltage is, if it is -35 V or more everything is good at this point. If you don't get voltages in the range of what I described, you have a wiring issue somewhere. Power the amp down and with a set (2) of clip leads with a 47 k Ω to 100 k Ω resistor clipped between them, connect each terminal of the can cap to ground for a minute or so. After you have done this, use your voltmeter to verify you have discharged the high voltage stored in the cap. Carefully go over all your wiring and correct any errors. If you did get the voltages described, put in all the tubes, connect a speaker or dummy load to the outputs and a signal source to the input. (Make sure the volume control is turned all the way down.)

If everything looks good, bring the variac voltage up to your normal line voltage. (Mine is usually 122 VAC.) Let the amp warm up for 5 minutes, but do a quick check of the voltage on the fuse you installed. It should be about 445 VDC to 458 VDC, if it is well below this you have an issue somewhere. If it is between 420 VDC and 480 VDC, check the negative bias on pin 5 of the output tube. It may be quite high (more than -41 V is good) slowly turn the shaft of the pot and try to get and try to get about -42 V to -45 V.

Now recheck the voltage at the fuse. You might find it has come down some as the output tubes start drawing current. Use

**MIC CAPSULES
ALL TYPES**

STOCK + CUSTOM

**Mic Capsules
Housings + Mounts
Lead Attachment
Connectorizing
Waterproofing
Wind Screens
Circuitry
PCB Assembly
Testing**

**Mic Assemblies
For Any Purpose**

Low Minimums

**HOW MAY WE
HELP YOU?**

JLI ELECTRONICS
215-256-3200

www.jlielectronics.com

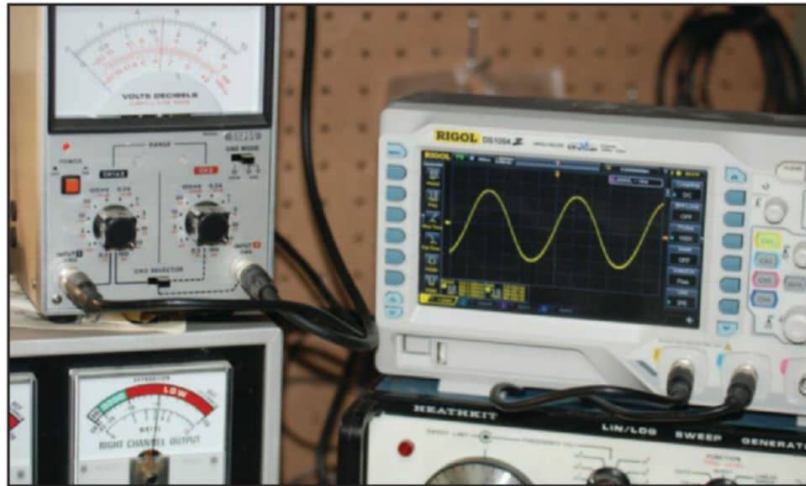


Photo 5: This particular amp produced 33 W RMS with a 400 Hz perfect sine wave.

the schematic test voltages on each of the tubes in the amp to determine if they are all in a 10% range of the schematic value. If all the high voltage DC measurements are lower than specified, you may have to go back and disconnect the 125 V winding and connect the 117 V winding. I very seldom have had to do this. If they are 10% on the low side, don't get too excited as the amp really doesn't care that much and it will extend the life of the tubes. If you have a metered variac, the amp should be drawing 0.7 A to 0.95 A. Let's assume at this point you are very happy with your results, things look good. Now advance the volume control and listen to the music!

The Listening Tests

Recheck your voltages and tweak the bias control pot. Depending on the year of the amp, McIntosh specifies -41 V to -45 V (with no signal). I have one schematic that says -35 V, but I believe it is a misprint. The more negative voltage you apply to the grids (-45 V vs. -41 V), the less current the tubes will draw and consequently the less power they will produce. I set the voltage to -43 V to -45 V on all the amps I have rebuilt. When output testing these amps, most 30s will produce 32 W to 36 W of perfect sine wave. My assumption is that McIntosh was very conservative in their specs.

About the Author

Bruce W. Brown has been experimenting with electronics and building stuff since the 1960s. He started his own business at age 15, installing house intercom and stereo system sand building Heathkit and Dynaco stereo amps for sale to friends and family (or anyone who wanted to buy one) He worked repairing stereo equipment for an audio store during his years in Pharmacy School. He has been a long time tube amplifier builder and restorer as well a contributor to *Glass Audio* and *audioXpress*. He restores tube amplifiers, and constructs custom amplifiers at his business, Vintagetubeaudio.com. He is happy to reply to questions at his email, Tuninfork@aol.com.

I usually let the amp run for 30 minutes or so and then recheck all the voltages. You might need to tweak the bias a little more as the tubes burn in. Once you are happy with your results, power the amp down and let it sit for 30 minutes or so. Unclip the leads that go to the bias AC and diode and measure the value with an ohm meter. Select the closest value to that from your 0.5 W resistor stash. I have found that most of the time it will be in the 1 k Ω range with amps that pull the bias voltage off the separate tap of the transformer. If your amp pulls bias off the 5U4, it is usually in the 5.6 k Ω range. Remember more negative voltage is better than less. Solder the selected resistor in the location you had the pot connected and repeat the voltage checking process. If you have one of the amps that had a separate bias winding your value may be substantially different.

Now turn up the volume and let the amp run for an hour or two and recheck everything again. If you have no issues, you are finished with that amp. I always use a Sharpie to write the date of the rebuild and sign it, so I always know when the work was completed. I also write down the bias voltage the amp is set at. This particular amp produced 33 W RMS with a 400 Hz perfect sine wave (see **Photo 5**). Driving the amp to higher levels, it produced 36 W with a slight flattening of sine wave.

Additional Improvements

There are other things that you can do to a 30 to improve reliability and operation, but I didn't have space for step-by-step directions. My late friend Larry Deruyter used to stick a choke under the chassis (there is plenty of room) and build a bracket to hold to existing bolts. He used it in place of the 150 Ω 10 W resistor—a 150 mA 7 H choke (Hammond 159Q). It cuts down on heat and he thought it made a difference in sound. (Sorry I didn't, but way too many years of loud rock music and handgun shooting.) Something else he used was an Inrush Current Limiter (Digi-Key KC006L-N) rated at least at 2 A. He would put one of these in the AC line going to the fuse to prevent AC surge to the filaments.

If I remember correctly, it was about 25 Ω cold and as it warmed up the resistance dropped. They do get quite hot and I was never a fan of adding more heat to a tube amp. Please make sure if you use one that there is nothing close to it, this means wiring or components. He also added capacitance to the 80 mfd and 20 mfd sections of the filter cap. If you used the Authenticap, you have already increased that 20 section to 50 mfd. He would glue some high voltage snap in caps to the chassis and back panel and parallel them with the 80 and 20 sections. He would add 50 mfd to 100 mfd to the 80 and 100 mfd

to the 20 mfd section. He said he got an improvement in the bass response. Something you might want to try, but I am very happy with the sound and power of my 30s. Do not under any circumstances add capacitance to the 40 mfd section before the 150 Ω resistor. This would stress the 5U4 tube on warm up and you really gain no benefit.

While on the subject of the MC30s, as I mentioned the tag boards are phenolic and extremely brittle at this point in their lives. I have four 30s butt their tag boards are butchered. I was going to make new tag boards for their rebuilds, but my friend, Patrick Brunner (a contributor to *audioXpress* and designer of medical electronic equipment for 50 years) is working to design a new circuit board to replace the current tag board. It will use the standard parts that I normally use (as well as carbon film 5% or 1% resistors) but will be a double-sided, silk-screened, solder masked board with all the components on one side, it will have nice heavy traces and a ground plane and it will be made out of FR 4 high-quality material.

I plan to write an article on this and the restoration using state-of-the-art (not surface mount) components. I know some of you may be

horrified by this idea, but the original phenolic tag boards are 25 years past their normal life span (and most show it). This board will be the same size as the original board and the L brackets bolt to the original bolts. He designed it to be very easy to install just by removing all of the wires going to the tag board. Virtually all leads will be long enough to connect to the bottom edge of the new circuit board. It is a very elegant design and it allows use with any version of the 30. It also removes the resistors and capacitors that hang from the front panel pot and terminal strips. I have received the boards and I am in the process of build a couple amps with them. I hope to write an article about these amps in the next few months.

I hope you enjoy your restored MC30 amplifiers, as I said earlier, they are the best of McIntosh and maybe the best small tube amps ever built.

Author's Note: As I have stated in my other articles, I am happy to answer emails with questions or issues you may have, however, I can't rebuild or service your amp remotely, so be reasonable. My business is Vintagetubeaudio.com and my email is Tuninfork@aol.com.

Celebrating 40 Years!

ACOustics begins with ACO™



Measurement
Microphones
Polarized and Electret

Community/Industrial
Noise Monitors/Alarms
Indoors and Out



Microphone Systems
Standalone
IEPE Powered
Phantom Power
Custom



Windscreens
3 to 18 inch & Custom
Weather/UV Resistant



ACO Pacific, Inc

www.acopacific.com sales@acopacific.com
Tel: +1-650-595-8588



www.swanskits.com



Build
something
you both will
remember.....

available on amazon.com

Sigma 100 (Part 1)

Designing the Satellite/Subwoofer Loudspeaker System

In the first part of this two-part article, George Ntanavaras shares his design for the Sigma 100, a unique loudspeaker system with two satellite speakers and a single subwoofer.

By
George Ntanavaras
(Greece)

The Sigma 100 is a stereo loudspeaker system consisting of two satellite loudspeakers for the left and the right channel and one subwoofer common for both channels (see **Photo 1**). The satellite loudspeaker is a two-way closed box loudspeaker with a 5" woofer and a 1" tweeter. With its small size it can easily integrate in every room, ideally placed on a stand with its tweeter axis aiming at the ears height of the listener. The subwoofer is a closed box with a 10" woofer driven by its own power amplifier. For the crossover between the satellites and the subwoofer, two different solutions were implemented—one using a miniDSP 4x10Hd versatile DSP and another using a pure analog active crossover with op-amps.

The Satellite Loudspeaker Box Design

I wanted to keep the size of the satellite loudspeaker small and the construction simple so I chose a closed-box, two-way system. To begin, I had to choose the drivers. For the woofer, I selected the Visaton W130S4, a 13 cm (5") low midrange driver with a coated paper cone, an elastic rubber surround, and a 25 mm (1") voice coil. For the tweeter, I selected the SEAS 27TBCD/GB-DXT-H1499, an aluminum/magnesium alloy dome tweeter with a DXT acoustic lens technology to optimize the directivity. It has a fine mesh grid that protects the diaphragm and a rear chamber with acoustic damping that allows the tweeter, having a low-resonance frequency, to cross over at low frequencies.

I measured the Thiele-Small (T-S) parameters of the woofers before designing the box. I "broke" them in by operating them for a few hours with a very low-frequency signal (around 6 Hz to 7 Hz)

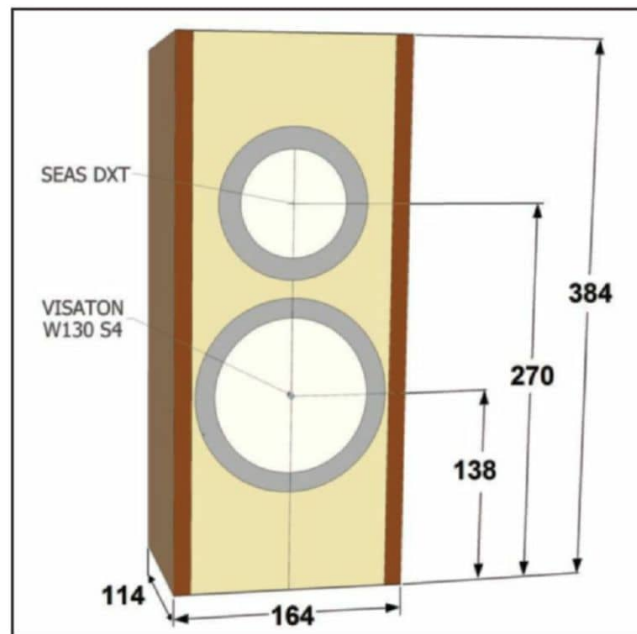


Figure 1: The dimensions of the satellite loudspeaker

at a voltage level that caused their cone to move considerably. The average values of the parameters for both woofers were: $f_s = 58.9$ Hz, $Q_{TS} = 0.51$, and $V_{AS} = 7.5$ ltr. With those three parameters, the closed box can be designed.

Choosing the volume of the closed box V_B , the resonance frequency of the box f_C and the quality factor of the box Q_{TC} can be calculated as follows:

$$a = \frac{V_{AS}}{V_B}$$

$$Q_{TC} = Q_{TS} \sqrt{1+a}$$

$$f_C = \frac{Q_{TC}}{Q_{TS}} \times f_s$$

The frequency f_{-3dB} where the response is down -3 dB depends on the value of Q_{TC} . For example, for $Q_{TC} = 0.7$ we have $f_{-3dB} = f_C$.

Applying the above values with $V_B = 4.2$ ltr, the formulas gave the following results: $a = 1.786$, $Q_{TC} = 0.85$, and $f_C = 98.2$ Hz.

The box dimensions are shown in **Figure 1**. I constructed it from 12 mm MDF and glued all the sides together with a good quality wood glue. I used a main horizontal internal brace, which was placed between the two drivers and separates the internal of the box in two parts. A lot of openings in the brace assured that the total volume of the box was seen by the woofer. I loosely filled the box with lamb's wool to lower the Q_{TC} and the resonance frequency. I sanded the external of the box and I applied several layers of a wood imitation varnish to have a nice looking. One of the completed satellites is shown in **Photo 2**.

I sanded the external of the box and I applied several layers of a wood imitation varnish to have a nice looking. One of the completed satellites is shown in **Photo 2**.

The Satellite's Passive Crossover

In designing the crossover, my two primary requirements were the flat on-axis response and the uniform horizontal polar response. For good spectral balance in a room, the horizontal polar response curves should be smooth replicas of the on-axis response. This is possible up to a limit because of the natural roll-off of the tweeter at higher frequencies and larger off-axis angles.

I mounted the woofer and the tweeter in the enclosure and I measured their polar responses. The loudspeaker was placed on a stand in the middle of a large room with the tweeter at 1.35 m above the floor (half of the room height) and the microphone at 0.6 m, giving a gate window measurement of 6.5 ms, which offers a measurement accuracy above 150 Hz.

The measurements are shown in **Figure 2**. The woofer shows a wider dispersion at about 1,100 Hz



Photo 2: One satellite loudspeaker



Photo 3: The crossovers of the satellites loudspeakers

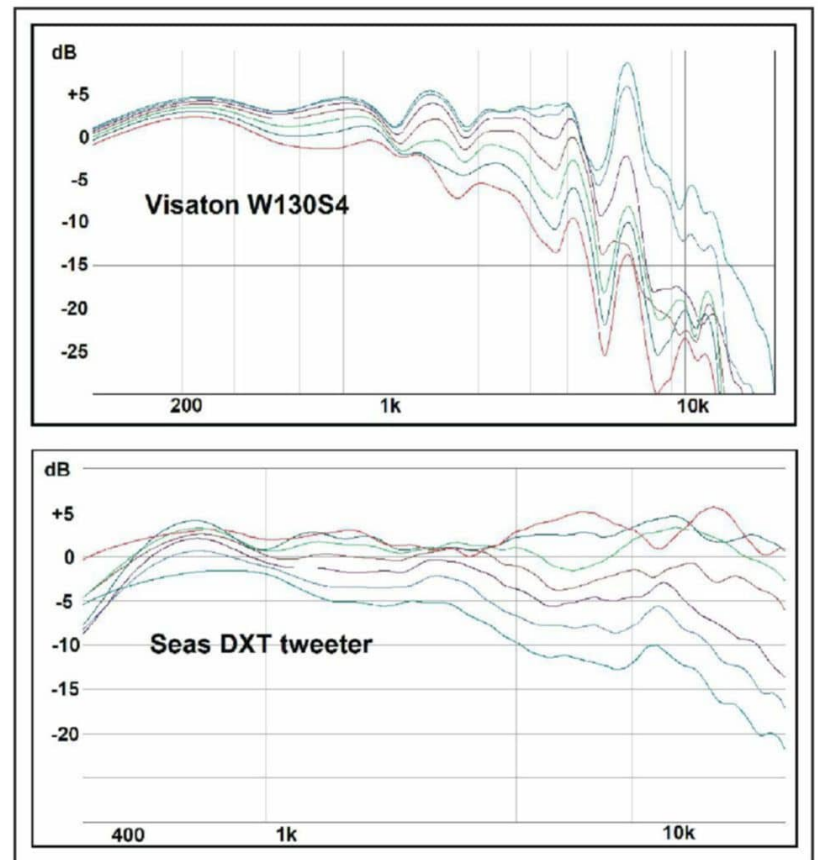


Figure 2: The horizontal polar response of Visaton W130S4 and the SEAS DXT tweeter

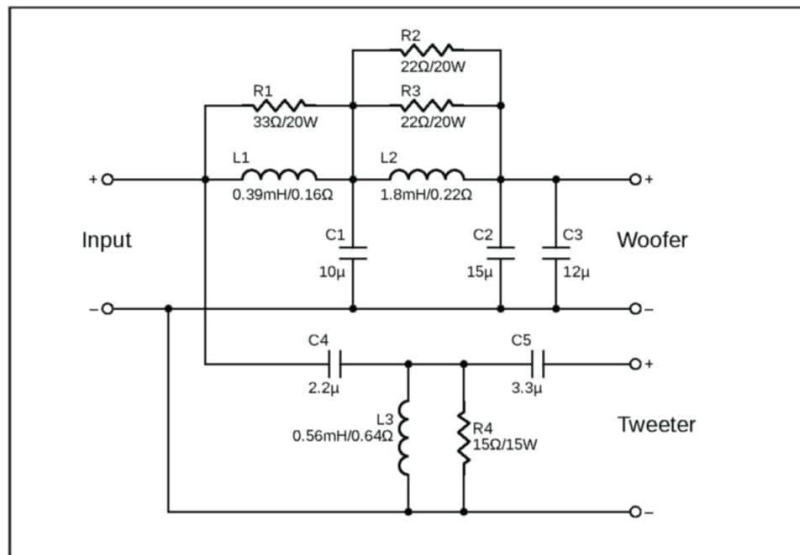


Figure 3: The crossover of the satellite

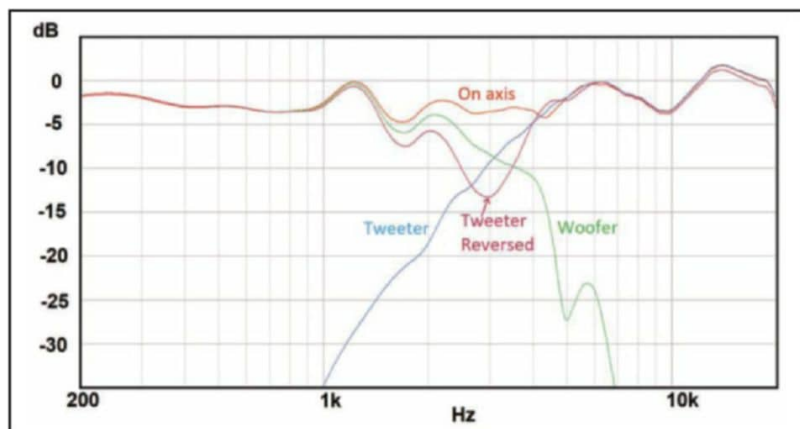


Figure 4: The response of the woofer and the tweeter

About the Author

George Ntanavaras graduated from the National Technical University, Athens, Greece, in 1986 with a degree in Electronic Engineering. He currently works in the Development Department for a Greek electronics company. He is interested in the design of preamplifiers, active crossovers, power amplifiers, and most loudspeakers. He also enjoys listening to classical music.

Resources

Arta & Limp software, www.artalabs.hr

V. Dickason, *The Loudspeaker Design Cookbook*, 6th edition (currently in its 7th edition), Audio Amateur, Inc., 2000.

G. Ntanavaras, "Accelerometer Testing of Loudspeaker drivers," *audioXpress*, June 2011. The article is available at: www.audioxpress.com/article/Test-your-speakers-performance-with-this-do-it-yourself-measurement-system

becoming more directional above this frequency with smoothly controlled off-axis behavior up to 3.5 kHz. The tweeter has also a very smooth polar response with a wider dispersion at the region of 2.5 kHz. Above 10 kHz, it rolls off as expected.

For the design of the crossover, I used the miniDSP driving the woofer and the tweeter with separate amplifiers. This gave me the ability to easily try different crossover frequencies and topologies. In all the cases, I measured the total polar response of the loudspeaker looking for the smoothest. After a lot of measurements, I chose a Linkwitz-Riley crossover at 3 kHz.

The final circuit diagram for the passive crossover is shown in **Figure 3**. The woofer's crossover is a fourth-order low-pass filter comprising of L1, L2, C1, C2, C3, R1, R2, and R3. The tweeter's crossover is a third-order high-pass filter comprising of C4, C5, L3, and R4, which with the tweeter loss at the lower frequencies becomes an acoustical fourth-order filter. Both drivers are connected in phase. Next to the value of the each inductor, its internal DC resistance is indicated. I used air cored inductors for L1 and L3 and an iron core inductor with 1 mm wire for L2 because I wanted this inductor to have a lower internal resistance since it is in series with the woofer and otherwise will lower the sensitivity of the loudspeaker.

I used film capacitors with very low loss factor and wire-wound power resistors. It is very important to use very high power resistors (20 W or higher) for R1, R2, R3, and R4 as shown in Figure 3, and install them in a way that provides them with adequate ventilation. I glued all of them on four pieces of plywood, two for the woofers and two for the tweeters, because it was easier to put them inside the small satellite boxes. The assembled crossovers are shown in **Photo 3**, on the right are the two crossovers for the woofers and on the left are the two crossovers for the tweeters. I placed them on the back side of the cabinet using thermal glue.

Satellite Loudspeaker Measurements

All the measurements were performed with the microphone at 0.6 m aiming at the center of the tweeter. The individual frequency responses of the two drivers are shown in **Figure 4**. The notch at the crossover frequency with the tweeter inverted indicates that they are in phase around the crossover frequency.

Figure 5a shows the loudspeaker's horizontal polar response with measurements taken on axis and at 15°, 30°, 45°, 60°, 75°, and 90° off-axis. **Figure 5b** and **Figure 5c** show the vertical dispersion of the loudspeaker with the measurements taken on axis and at 5°, 10°, and 15° above and below the axis of the loudspeaker.

I measured the impedance using the LIMP software and its magnitude and phase are plotted in **Figure 6**. The minimum value is 4.4 Ω at 180 Hz and 2.4 kHz with the phase close to 0°. The maximum value is 15.6 Ω at the box resonance frequency (92 Hz). It ranges from +37° at 65 Hz to -35° at 115 Hz.

I used my accelerometer system to check the vibration behavior of the loudspeaker box. The system consists of the ACH-01-03 accelerometer, an amplifier that computes the velocity and the displacement, and an external power supply adapter. This is an improved version of the design that I presented in *audioXpress* magazine and is posted online on the audioXpress website (see Resources). I attached the accelerometer to the panels of the cabinet and I used the ARTA software. The excitation was a 60 Hz high passed pink noise signal. A power amplifier drove the loudspeaker with this signal at a high sound level.

Figure 7 shows several measurements. The top curve is the reference and it was taken with the accelerometer attached to the center of the woofer's cone. The other four curves are vibration measurements of the loudspeaker box's sides as described in the figure. They are almost 50 dB lower than the reference except around 440 Hz where they are around 30 to 35 dB lower. An interesting measurement is the one I took with the accelerometer attached to the ABS plastic material of the loudspeaker terminals on the back side of the loudspeaker. As shown, this is a very noisy point, almost 10 dB louder in the region of 80 Hz to 90 Hz, but fortunately it has a small area. This measurement proves that we should pay attention to every detail if we want a cabinet with very low vibration noise.

Designing the Subwoofer

I selected the Peerless 830452 driver for the subwoofer. Peerless has a very good reputation for its subwoofer drivers and this 10" driver is no exception. According to the manufacturer, it has an "Extra Long Stroke" capability for very long voice coil excursion, an effective piston area of 350 cm² and low distortion.

The construction of the unit is impressive. I measured the T-S parameters and the values were: $f_s = 18.9$ Hz, $Q_{ts} = 0.17$, and $V_{as} = 89.6$ ltr. I choose a closed box because the transient response is better and the response decreases by only 12 dB/octave so it can be electronically equalized more easily.

I choose a box volume $V_b = 35$ ltr as a compromise between the size of the box and the needed power amplifier drive voltage.

Applying the same formulas as before, I received the following results: $a = 2.56$, $Q_{TC} = 0.32$, and $f_c = 35.6$ Hz. The resonance frequency of the box

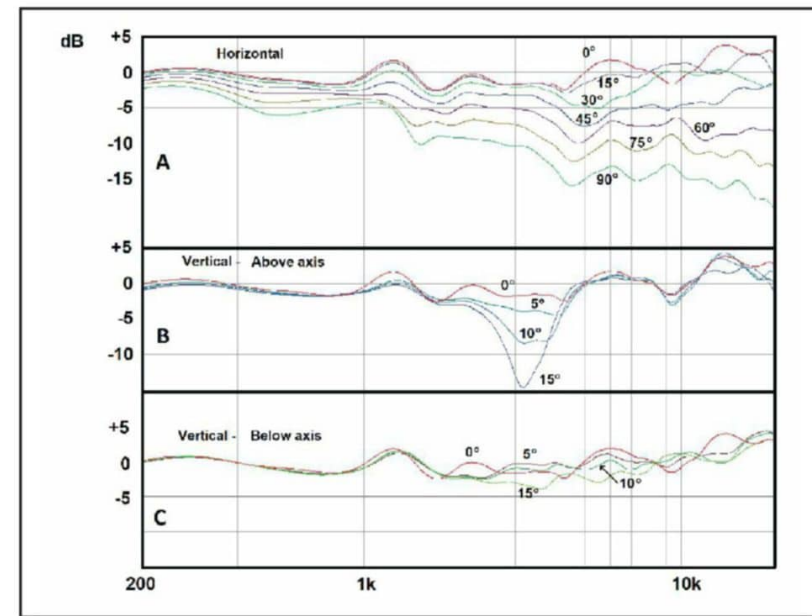


Figure 5: The polar response of satellite

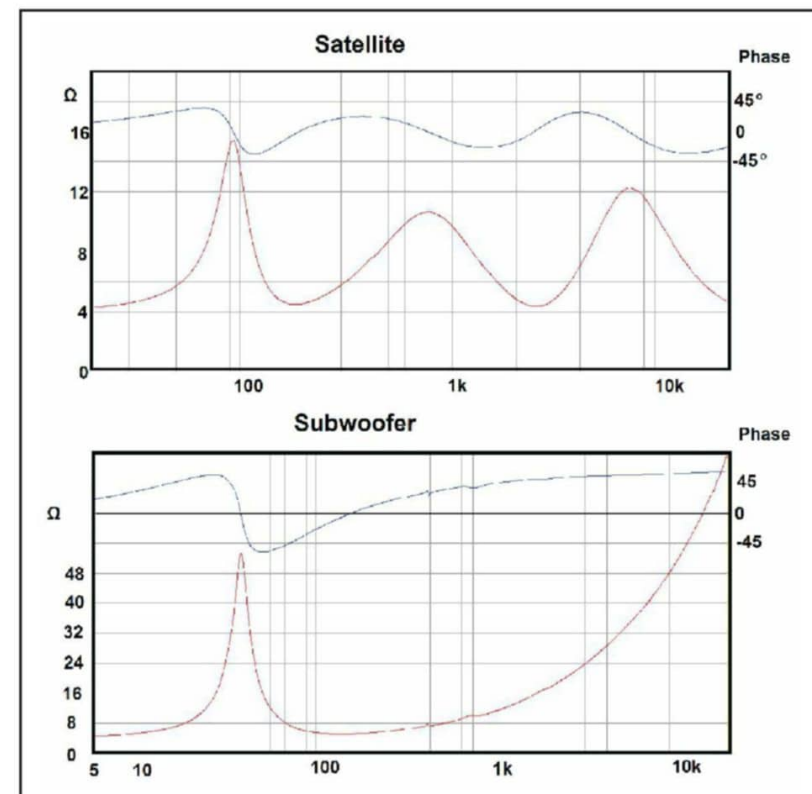


Figure 6: The impedance of the satellite and the subwoofer

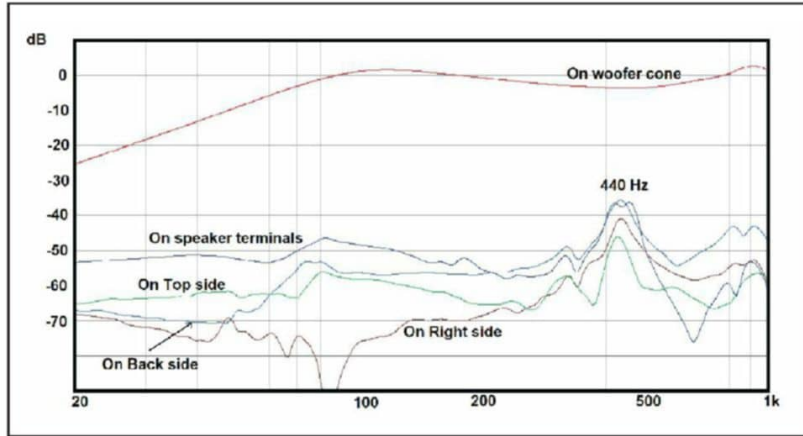


Figure 7: Vibration measurements of the satellite cabinet

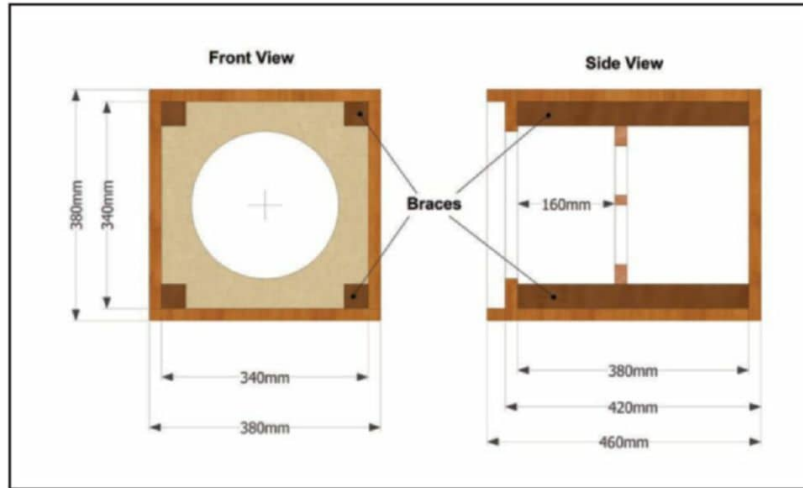


Figure 8: Subwoofer box dimensions

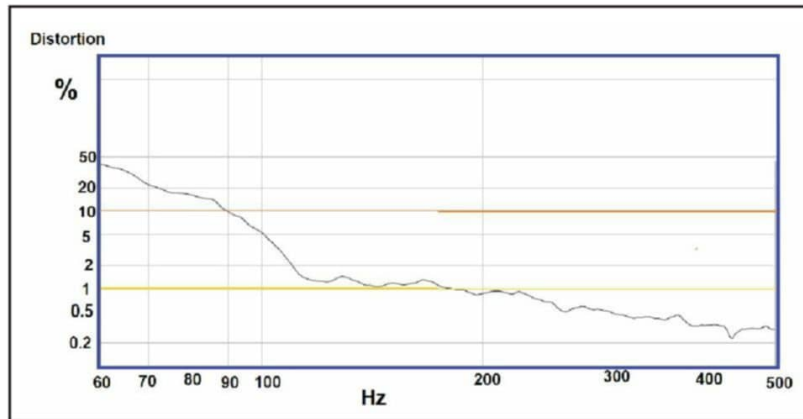


Figure 9: Distortion of the satellites at 8 VRMS

is high for a subwoofer and the Q_{TC} is very low and they will be corrected with the electronic equalization.

The drawing of the subwoofer box is shown in **Figure 8**. The box's internal dimensions are 340 mm × 340 mm × 380 mm, and the external measurements are 380 mm × 380 mm × 460 mm giving an internal volume of 44 ltr and an external volume of 66 ltr. If the volume occupied by the driver and the internal braces are subtracted, the box's net volume is 35 ltr. I constructed the box from 20 mm plywood using corner braces as shown in Figure 8. In the middle of the box, I glued an internal brace with large openings to increase the rigidity of the box and minimize the panel vibration. I didn't use any internal stuffing because the subwoofer will be used only in the low frequencies. I painted the box with a wood imitation varnish similar to the satellites.

I used the LIMP program to measure the impedance of the subwoofer box shown in Figure 6. The program calculated the parameters $Q_{TC} = 0.36$ and $f_C = 34.8$ Hz, which are very close to the theoretical values. The maximum impedance magnitude is 54 Ω and the minimum is 5.1 Ω at 120 Hz with the phase close to zero. A small "glitch" in the impedance curve at 400 Hz caused by a standing wave corresponding to the large dimension of the subwoofer box is not a problem since it is far above the subwoofer operating range.

Selection of the Crossover Frequency between Satellites and Subwoofer

The crossover frequency between the subwoofer and the satellites is determined by the low-frequency performance of the satellites and usually ranges between 40 Hz to 120 Hz. When only one subwoofer is used for both channels, the sound coming from the subwoofer should not be localized, so the crossover frequency has to be as low as possible.

Components for the Satellite Crossover

Capacitors

(All capacitors 250 V, MKP)
 C1 = 10 μ F
 C2 = 15 μ F
 C3 = 12 μ F
 C4 = 2.2 μ F
 C5 = 3.3 μ F

Inductors

L1 = 0.39 mH, 0.16 Ω , air core
 L2 = 1.8 mH, 0.22 Ω , core coil
 L3 = 0.56 mH, 0.64 Ω , air core

Resistors

R1 = 33 Ω /20 W, ceramic resistor
 R2 = 22 Ω /20 W, ceramic resistor
 R3 = 22 Ω /20 W, ceramic resistor
 R4 = 15 Ω /15 W, ceramic resistor

I performed some distortion measurements to help make the right selection of the crossover frequency. I set the output of my test amplifier at a voltage level of 8 V_{RMS} (22.6 V_{PP}) and the microphone close to the woofer of the satellite. The distortion shown in **Figure 9** is low down to about 110 Hz and then starts to increase quickly. I selected 100 Hz as the frequency of the crossover because both the subwoofer and the satellites will reproduce this region.

I also investigated the ability of the subwoofer to clearly reproduce the very low frequencies to define the limit of the low frequencies electronic boost before any overload arise due to very high excursions. I set the output of my test amplifier at a voltage level of 10 V_{RMS} (28.3 V_{PP}) and I performed a distortion measurement for the frequencies between 10 Hz and 90 Hz as shown in **Figure 10**. The subwoofer performs well down to 50 Hz with the distortion between 1% to 2%. Below this frequency, the distortion gradually increases. I decided to set the -6 dB cut-off frequency of the subwoofer at 26 Hz.

Next Month

In the second part of the article, I will continue with the active crossover that I used for the satellites and the subwoofer, describing two cases. One with the miniDSP 4x10Hd multi-channel DSP device, and the second with a completely analog active crossover based on op-amps. **ax**

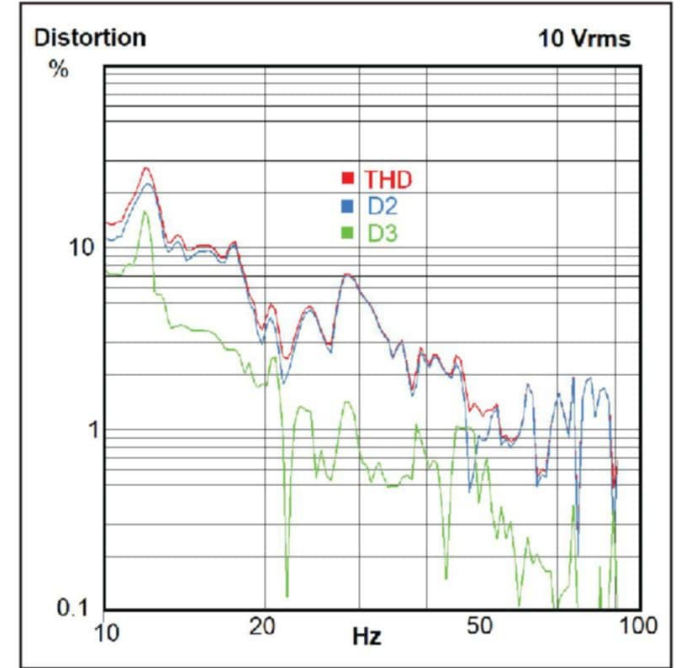


Figure 10: Distortion of the subwoofer at 10 VRMS

BEST TESTING

Experience cutting-edge technology that enables true-to-reality and comprehensive tests for your headphones, headsets and hearables.

HEAD acoustics, Inc. • info@headacoustics.com • www.head-acoustics.com

Innovator Pushes the Envelope of Technology

An Interview with Bradley Pfeifer

By
Shannon Becker
(United States)



Bradley Pfeifer is hoping to provide the audio industry with more organic, earth-friendly options. He currently works as an outside sales development engineer with Nevada Assembly Service (NAS Electronics Manufacturing), a contract state-of-the-art factory located in North Las Vegas, specializing in “Made in USA” audio products manufacturing.

SHANNON BECKER: Tell us a little about your background. How did you get involved in the audio electronics industry?

BRADLEY PFEIFER: One could say I was naturally born into an “engineering/musical family.” My father was a gifted aerospace engineer/mathematician who was on the early pioneering team that helped Jack Kilby (Texas Instruments fame) invent the world’s first successful integrated circuits (ICs). My mother was a housewife that was also musically talented. She played piano, guitar, and also taught dance instruction at the various school functions as I was growing up. My father’s favorite hobby was “fine woodworking” (focused on furniture), so this is where I obtained my skills in building speaker cabinets and other wood-working, craftsman-based, projects as time progressed into my teenage years. My dad helped me build analog synths, power amplifiers, PA speakers, guitar amps, and guitar pedals such as power boosters, fuzz boxes and phase shifters. This was in the mid-1970s when “Analog was King.” I had no idea at the time how important that would become later in life. Subsequently, I fell

in love with the unique sonic signatures of the Mini Moog, ARP Odyssey, and the early Oberheim analog synthesizers. They changed the music scene back then and I was always excited to hear new songs of the day made with those classic synths. However, those analog synthesizers were very expensive back in those days, so I played rhythm guitar in my first rock band and then later in high school, I gigged around Orange County, CA as a lead guitar player in a local rock band playing cover tunes of the day. My favorite rig back then was a 1975 British Orange Amp OR120 half-stack and a 1974 Mosrite Les Paul-style guitar. I built a custom “triple-stage” power booster (from a modded LPB-1 circuit).

Looking back now... I learned the power of mathematics from my late father and that just about anything on earth could be broken down into physics, chemistry, and/or mathematics. My father always seemed to have an answer and explanation for just about everything in this world. Black Holes, Anti-gravity, Chaos mathematics, Physics, he loved it all. I realized I was quite a lucky kid to have a father like I did. He could teach me almost anything and I tried to learn as much as I could from him. He was

also very kind to my childhood/teenage friends that I would bring to the house to help build audio or amp/speaker projects. He was a kind, spiritual man and a great teacher to all my friends. In summary, all of the above “set the stage” for my future career in the audio/music/electronics industry. There is zero doubt about this fact and my late father was a huge influence on my life/career.

BECKER: You currently work at NAS Electronics, Inc., in Nevada. What is your role with the company and why the move to Las Vegas?

PFEIFER: My title at NAS Electronics is “Sales Development Engineer.” This encompasses a few different things including Outside Sales—attending trade shows, networking on LinkedIn social media, visiting with customers to aid in the manufacturing of their products (PCB assembly and full-turnkey box builds). I also focus on business development—linking electronic component/suppliers to NAS Electronics. And, I am a product/component Engineer—helping our new and existing customers with improving performance of existing products through specialized BOM selection of components.

I currently reside in both Southern California and Las Vegas these days. However, the push to Las Vegas was strictly due to the fact that Nevada is one of the most economically friendly and advantageous places to set up “Made in USA” electronic manufacturing on the West Coast of the US. Tesla did the same research years ago and set up in Reno, the other “modestly populated” area in Nevada which is physically closer to Silicon Valley. It makes complete sense, if you think it through. In addition, since most of Nevada is desert these two areas (Reno/Las Vegas) are “the places to be” with regard to manufacturing, as far as I’m concerned. Las Vegas has the advantage of being only a 5-hour drive from Southern California, which is one of the highest ranking economies in the US. The key is that Nevada offers Zero Corporate Taxes, Zero personal income taxes, and has nearly 50% lower housing and electricity costs compared to Southern California. Yet is only about 300 miles away! This is why NAS Electronics is located in Las Vegas, NV and we are poised for rapid growth in all things electronic and audio-related manufacturing, while still proudly bearing the “Made in USA” product tags for all our prized customers!

So in summary, the move to Las Vegas started when I was heading up the Southern California-based audio start-up known as PerSuede Audio, and we strongly desired to manufacture all our audio products in the US, since “we saw the writing on the wall in advance” (circa 2013), with continuing to



Nevada Assembly Service (NAS Electronics Manufacturing) is located in North Las Vegas and specializes in manufacturing audio products from prototype to production of bare printed circuit boards, and full turnkey assembly.

deal with the “Made in China Syndrome,” namely, the counterfeit electronic components, the difficulty in manufacturing ultra-high quality products in China, the long distance travel and all the hidden expenses associated with it, the language barriers, the “never decreasing” but “continuously rising” labor rates, the new tariffs, and most importantly, the I.P. that we had to share/divulge in order to build our products there. All in all, we simply felt that for us, it was not worth the time, expense, lost I.P. and all the other factors involved. Again, if you think it through, it is actually very expensive to partner with China these days. There are hidden costs all over the place!

What we also learned is that once we decided to make the switch back to “Made in USA,” all of a sudden, the challenging things like obtaining and sourcing high quality Tier 1 electronic components, high purity copper cabling, hybrid wood cabinet and dampening materials (many invented in the US), were no longer an issue to source. It was truly an awakening. We realized that if one is to build a super high-quality product in China, it is always going to be a huge up-hill battle. It’s really so much easier to do it here! The downside is the increased finished product price, but I believe Americans are much more willing and ready to pay for real quality these days and also help our country out in the process in terms of preserving American I.P. and our unique creative manufacturing processes.

BECKER: Can you tell us a little about your position and how you got involved with surface-mount technology (SMT)?

PFEIFER: My tenure at Audio Components International (ACI) in 2004 introduced me to the



NAS Electronic Manufacturing is a ISO9001:2015 Certified manufacturer with large capabilities in printed circuit board (PCB) manufacturing, from state-of-the-art Surface Mount Technology (SMT) to manual assembly processes.

world of electronics manufacturing. Most specifically, electronic “audio-related products” manufacturing with a few select China based factories that we were tied to at the time. While I was involved with projects that employed SMT technology, such as sub-woofer plate amplifiers, I really was not heavily involved with the technology at that time, since I was not part of the circuit design aspect of the production of those products. I was mainly focused on managing speaker driver related products at that time such as in-wall CE speaker products and Musical Instrument (MI) speaker cabinet products, for example. However, this speaker driver work experience helped pave the way for my ability to develop custom high-end speaker drivers later on in my career.

Well... fast forward to 2008, when I co-founded PerSuede Audio, with a Norwegian/American partner, friend of mine in Camarillo, CA, who owned a consumer electronics warehouse distribution firm. I was in charge of creating/developing the next generation of compact, world-class, high-end audio consumer electronic product(s) all centered around the rapidly growing MP3 players of the day, namely the Apple iPod and subsequently, the Apple iPhone, and so forth. While the MP3 file format had its short-comings to many audiophiles and purists, it was still revolutionary in the fact that it enabled us, for the first time, to carry around our “entire music library” in a small, compact device such as an Apple iPod Nano. This was a huge change from years gone by for musicians, audiophiles and music lovers alike. My dream/goal was to “extract

as much music as possible” from this new music storage technology and play it through a new level of high-quality speaker product technology that would change the way we see and hear music.

At that time, we did not care how much this new product would cost, but rather how far could we push the “envelope of technology” to achieve this goal. Many thought we were crazy at the time, but the future proved that we were not alone in our beliefs and thinking, as the CE market marched forward with products that “claimed” revolutionary performance, none the same, and offered to consumers at record setting higher moving target prices.

Nevertheless, in order to achieve this goal, I spent the majority of 2008 and early 2009 doing research and testing on a number of compact audio amplifier technologies available at that time and it was my musician’s ears that lead me to a particular Class D amplifier sound and subsequent technology that was very unique. This is how I met Jan Peter Amerongen and his design partner, the infamous Bruno Putzeys—the modern day front-runner/inventor pushing Class D audio amplification technology majorly forward from the Netherlands.

By 2009 ~2011, I worked directly with these two audio engineering experts in Europe to develop a new compact Class D amplifier solution from my office/lab in Camarillo, CA that was a game-changer, as far as I was concerned. Compact, lightweight, potentially portable, high-quality audio amplifiers that had no heavy transformers or heatsinks and that could be manufactured at controlled, modest cost with audio performance that was truly remarkable at that time.

The subsequent Class D amplifier technology and designs we created employed hybrid electronic PCB build topology, which employed thru-hole components on the top side and SMD components on the bottom side of the PCBs. Subsequently, this is how I became heavily involved with SMT technology and the specific SMD components that made up the SMT technology for audio applications and finished high-performance audio products. It did not take me long to realize that not all SMD components were created equal; no different than thru-hole components, of course, when employed in audio circuits. Granted, the tried and true thru-hole component manufacturers were well known and identified at that time. Thru-hole electronic audio product specialized components from Wima, Germany and PRP in Iowa, for example, were all the rage in high-end audio equipment. But what about this new SMT/SMD technology? What were the killer sounding audio components to be employed in

world class compact audio products? How were we to gain a better understanding of this? I knew I had to master this understanding if I was to be at the top of my game in the world of world-class performing, compact audio speaker product offerings.

The answer to this question was that SMD component selection for audio products was still a fairly unknown territory to most audio engineers/designers, which I needed to explore/understand in order to push the envelope of technology to the next level. Of course, there were still some audio engineers that considered it all non-sense, however, we knew better, simply because we could “hear the difference” and it “meant something” to us. Thus, my new journey began... and I was determined to better understand the world of SMD components and their relationship to sonic quality and harmonic output complexity, otherwise known as musical “timbre.” This, in time, taught me the importance of “material composition” in audio components and the fact that all passive audio components all have their unique “sonic signature” harmonic output based upon their material composition. This of course, is the same with “thru-hole” components as it is with “SMD components.” I remember that back in circa 2009, I had no idea whether “thick film” or “thin film” SMD resistors were superior for use in audio circuits. My ears “taught me a ton” as I embarked upon my new journey, burying myself in my lab for years testing all kinds of SMD components for audio performance and harmonic timbre output & working with initially Asian production factories and later US-based EMS factories in order to create initial product(s) and prototypes for the start-up, known as PerSuede Audio.

BECKER: What appeals to you about SMT and how has it evolved?

PFEIFER: SMT technology and the subsequent SMD electronic components that make up the technology are very appealing to me for a number of reasons. First and foremost, there has never been an electronic technology that enables us to design, create, and manufacture circuits in such a small, micro-sized, form factor. This has tremendous advantages and nearly endless applications in electronics and micro-electronics, such as hearing aids and active noise cancellation audio products, not to mention outside the audio industry to such notable products as compact test equipment and/or robotics/controllers. If you think about how large the old vacuum tube products of the first half of the 20th century were, it is mind-boggling to realize what we are capable of today with SMT technology based,



Organic Vibrations Audio is a development project that Bradley is working on in his spare time. His goal is to join them together in concert in the future with NAS Electronics acting as full-time manufacturer of all OVA products.

electronic manufacturing and production. Since my career specialty is with audio-related products, we can envision analog music synthesizers, for example, with massive numbers of oscillators all possible with SMT technology at very modest cost, due to the incredibly small form factor SMT technology affords us. This translates to potentially game-changing and extremely powerful products.

Modern SMT technology affords us the ability to offer much more complex circuits that are more powerful and yet affordable, in the same form factor space. This is a huge step forward and advantage for designers and engineers in all facets of electronic product offerings. So this evolution of employing SMD components in an ever growing landscape of more complex circuits and products is the future of modern electronics, and the sky is the limit on where it can go. All definitely, not possible 30+ years ago for the same cost and/or size form factor.

BECKER: You mentioned a small speaker driver assembly line alongside of your SMT line of equipment. Can you share any more information about this upcoming endeavor?

PFEIFER: Indeed, I own SMT manufacturing equipment in Las Vegas and have recently teamed

This 70 mm midrange driver is made using an organic fiber recipe.



up with the wonderful people at NAS Electronics Manufacturing in Las Vegas to further expand the goal and vision of not only manufacturing high-quality, “Made in USA” electronic audio products, but offer them at modestly affordable prices to all our customers as well. This manufacturing concept is a change that I’ve been seeing for a while now as China and other Asian landscape offerings rear their hidden costs to us in more ways than are usually perceived at first. It’s not just about rising labor rates there that are constantly moving upward with time, closing the price gap. There’s much more to it.

Nevertheless, with this in mind, we have had some internal discussions about moving forward with an initially modest, small speaker driver assembly line in our Las Vegas factory to better serve our audio based customers. The initial goal would be low-quantity, high-quality production to start—with voice coils made with higher purity metallurgy and materials employed. Think about it, there are very few speaker driver manufacturers left in this country, yet we, as a country, were at the forefront of the speaker driver technology and industry all the way back to the 1920s. Folks like Hawley in KY have been making US-made speaker cones since 1917! So, I believe it’s time to move this manufacturing & technology gradually back to this country and keep the advances and improvements here as well. Sure, the finished speaker product cost(s) will be higher; but the quality can also be commensurately higher and the

performance better. There is simply no substitute for quality and innovation. Last I checked, there are many people who want to hear the most from their music. They all want to rediscover their music and savor the moment in the process. This is just one part of the puzzle that can bring us closer to our music. Components in speaker driver manufacturing such as higher purity copper voice coil wire and organic based fiber cone recipes are all wonderful things that keep me passionately glued to this amazing industry. My search for the ultimate musical truth will go on for as long as I am breathing on this planet earth.

BECKER: What is Organic Vibrations Audio?

PFEIFER: Organic Vibrations Audio (OVA) is the name of my latest audio endeavor, that in time, stands to bear musical fruit that I believe will change our understanding of musical reproduction with regard to the electronic technology and organic derived materials employed in the technology that will be a large part of the harmonic musical sound and timbre output of the new products.

While still in the R&D stage on many fronts, OVA will employ the latest SMD electronic component technology coupled with material composition of speaker drivers, and electronic components derived from as close to genuine organic mother earth derived materials/sources as possible in order to pour forth a sonic soundscape that will truly engulf us in our music.

This is based upon a unique belief that true high-performance musical speaker devices should be made and derived from as much organic, natural mother earth derived materials as possible. The technology pays homage and respects the beautiful understanding that I believe we don’t have the right to pollute the earth while we are here on this planet. I understand this is a bold statement, but please hear me out on this. The harmful repercussions to our subsequent offspring for generations due to our lack of understanding here are larger than we truly understand in my opinion. Humbly, this unique understanding takes into consideration of the fact(s) that when we develop a new technology that helps mankind, (whatever that might be), we simply should not release it to market until we have developed a way for it to bio-degrade back to earth once the useful life of the product is completed. Can you imagine what a better place this earth would be if we all had this design discipline? Straws, milk cartons, and such would be made from biodegradable paper. I believe that all audio products (as with all other products produced in this world) should set goals to understand and pay homage to this unique

bio-degradable understanding. Worse case, at least make an attempt to achieve some high percentage of biodegradability upon product release otherwise.

While this organic derived understanding may sound strange to some, if I cite some examples, I believe it will help paint a clearer picture without letting the cat fully out of the bag, so to speak on some of the future OVA technology.

For example, let’s discuss speaker cones for a moment... I believe that organic-derived natural fiber speaker cones portray musical output in a way that is unique and superior to employing man-made materials for the same applications of these same components. As such, I am a big fan of various organic paper pulp recipes, cotton, silk, hemp fiber and other unique organic-derived materials that can be explored and employed to produce a very vivid natural and lively sound quality, rich in midrange complexity if designed properly. While I am not at liberty to fully disclose all the understandings and recipes here, I believe our readers will get the idea. The end result is an audio sonic output that has very quick slew rate (attack) coupled with truly rich, complex harmonic sound output, which is what our

human ears enjoy and want to hear. Sure, we can employ man-made, non-organic, plastic-based PPV and Kevlar speaker cones that measure flat and have decent performance, but at what harmonic complexity factor?

Some of us have not pushed the envelope of technology forward far enough to know what we are missing when we do not respect mother earth and the biodegradable mandate of understanding that should be our goal. To put it another way, there are still a lot of elements of “old-school” technology from yesteryear that still withstand the test of time. Some of those vintage paper cone recipes from yesteryear are still sought after by “those in the know” in the audio industry and music scene... (in both the consumer electronic fields as well as the MI markets)—yet they were “all the norm” in the first half of the 20th century when we were aligned more closely to Mother Nature in terms of material composition. There is a lot to this understanding that cannot be written properly in an interview of this scope, but I think our readers will understand the concept that I am trying to convey. Other materials such as nitro-cellose lacquer, (derived from organic

EMPOWER THE MUSIC

**Read.
Design.
Build.
ENJOY!**

With this how-to loudspeaker book, you will be able to crank up the volume on a first-rate system that you designed and built yourself.

cc-webshop.com

Speaker Building 201

A Comprehensive Course in Speaker Design

by Ray Alden

With 11 completely designed speaker systems including a 5.1 home theater system

- Your guide to understanding the mysteries of speakers
- A perfect mix of theory and practical application

Build Your Own FIRST-RATE System

For Beginners and Serious Enthusiasts

nitrate cotton), natural beeswax and countless other closely organic derived products can be employed to bring about incredible realistic audio soundstage reproduction while respecting mother earth. Other examples are highly pure forms of the correct metals used to conduct electrons to their %IACS maximization as well as unique new technologies such as graphene from both graphite and hemp are all very promising and part of the new OVA technology.

BECKER: What do you see as the next “big thing” that will continue to push the envelope of audio technology forward?

PFEIFER: There are a few areas that without a doubt will continue to push the envelope of audio technology forward. The first and most obvious to me is “graphene.” “Graphite-derived” graphene is the most revolutionary and amazing material we have ever discovered. It’s the world’s fastest conductor... Yes, even faster than silver. Its %IACS electrical conductivity factor is off the charts! In addition, it’s 100 times stronger than steel and also has the ability to store energy and act as a super-capacitor, all in one. It could be used in applications such as aircraft wing material for its lightweight to strength ratio, and conduct electricity more efficiently than any other material we know of and at the same time, also store energy to boot! These are just a few of the incredible characteristics of this amazing material, which is a massive “game changer” in my opinion.

“Carbon,” an abundant earth resource is capable of forming many allotropes due to its valency. “Graphite-derived” graphene, is a single nano-layer of graphite and is subsequently an allotrope of carbon. Diamonds are also a common allotrope of carbon, just as graphite itself is still another allotrope of carbon. An allotrope is defined in its most basic sense, as the ability of an element (e.g., carbon) to have the capability of two or more different forms in the same physical state. As such, it’s amazing to understand how important carbon is to our world, let alone the future of electronics.

Another form of graphene that is less known in our industry is “hemp-derived” graphene. This new type of graphene also shows immense promise in many potential applications that unlike graphite-derived graphene, is actually “very affordable to produce.” Thanks to the work done by Dr. David Mitlin at Clarkson University, hemp graphene shows great promise in the world of electronics, as Dr. Mitlin and his team were successfully able to cook the organic hemp bark into carbon nanosheets and build super-capacitors with it. This is simply astounding in my opinion, and just another example of the power of

natural, mother earth derived “organics” in the world of electronics and more specifically, audio electronics.

Hemp comes from the stalk of the cannabis sativa plant species, which although controversial to some degree, can be used for many noteworthy positive uses for mankind. The “inner bark of the plant,” known as “bast fiber,” according to Dr. Mitlin, typically ends up in a landfill because no one really knew what to do with it initially. Sure, we can employ hemp “bast fibers” to produce textile materials to make clothing or other textile products, but who could have imagined that Dr. Mitlin and his team would successfully make electronic super-capacitors with it on par with, or exceed, the current performance of super capacitors made with traditional modern, arguably less organic methods? This is simply remarkable.

In summary, “graphene,” both graphite and/or hemp derived versions of this technology hold great promise in many areas of audio electronics. Audio components such as capacitors could benefit from graphene as the conductive sheet material as well as employing any combination of hemp/cotton/paper fiber-based dielectric material(s), which could even be semi-conductive, as to what was employed in the now legendary & infamous Rubycon Black Gate audio capacitors. Similarly, modern SMD versions of these specialized audio components could also be developed with remarkable results, no doubt, with pertinent examples being SMD audio resistors and other important components typically employed in audio electronic circuits.

Other areas of graphene usage that show great promise in the future can be found in such examples as future professional studio microphone product applications whereby both the microphone diaphragm (LDC) and the electronic components employed within; could have some form of graphene technology employed. The possibilities are simply endless. Armed with this profound understanding, we can develop and enjoy remarkable electronic and audio performance products that will not destroy the earth when we are no longer around.

This understanding and discipline is a major step forward from where we have been as an industry employing mylar, polycarbonate plastic, PPV, Kevlar and other forms of non-organic products that can’t offer the same characteristics and benefits. For starters, many of these materials cannot bio-degrade at all, let alone in the first 1,000 years or so. Furthermore, I support the fact that they don’t sound as “natural” either. United, we can make a positive difference in not only our industry, but in that of our precious earth and to others around the globe as well.

AUDIO. AMPLIFIED.

Audio is no longer a simple channel made of amps, microphones and other equipment; it’s become a vehicle to create experiences. Rethink what you know about AV. See the latest products and solutions at InfoComm.

Learn more about the power of integrated AV experiences at infocommshow.org.

YOUR FREE EXHIBIT HALL PASS IS WAITING
Register Today With VIP Code XPRESS

CONFERENCE: JUNE 8-14

EXHIBITS: JUNE 12-14

ORANGE COUNTY CONVENTION CENTER
ORLANDO

infoComm
infocommshow.org

Searching for a Unicorn (Part 2)

Generating a Good Signal Source

Testing a voltage regulator with exceptionally good performance requires an even more exceptional signal source and measurement setup. In the second part of this article, Brian takes us through 10 years of test refinement to measure sub-microVolt ripple across a wide frequency range.

By
Brian Lowe

(Belleson LLC)

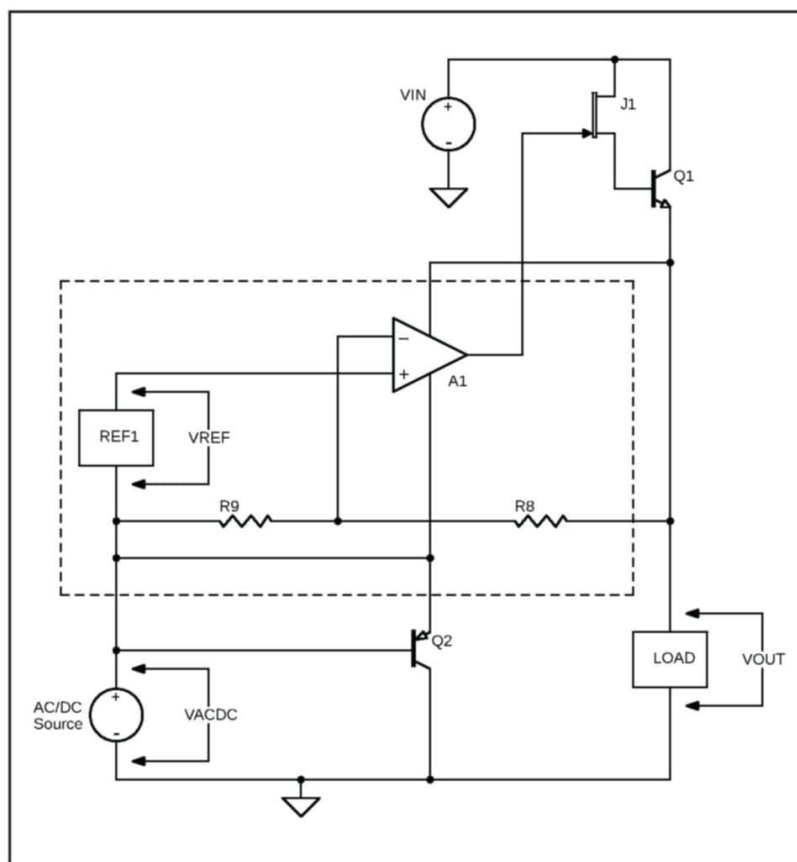


Figure 1: This schematic shows a floating reference loop to source DC+AC at regulator output.

In the first part of the article series, we discussed some “super regulator” designs and the performance we might expect from them. Here we continue by searching for the elusive unicorn of an accurate measurement by examining various measurement techniques.

Test Fixtures

The ripple measurement starts with a regulator input power source that combines a DC voltage with an AC sine wave ripple riding on it. Given a regulator that floats on a reference signal, what better way to get a sine+DC than float the regulator on a sine wave? Referring to **Figure 1**, see how VACDC will conveniently give the AC+DC needed to test a(nother) regulator. Savvy readers are already shaking their heads with an internal “no, that doesn’t work.”

And why not? Unseen on Figure 1 is the output capacitor needed to stabilize most series regulators, often in the range of 1 μF to 100 μF , in parallel with LOAD. Notice that this positive regulator can source current with the greatest of ease, but cannot sink it except through the load. So charge stored in the output capacitor cannot be drained away quickly enough. Thus, the higher the frequency sine wave you attempt to get from the regulator, the more distorted is the sine wave on top of the DC output.

This is also a reason you don’t want to use a positive regulator with reversed input supplies to regulate a negative voltage, which I’ve seen in

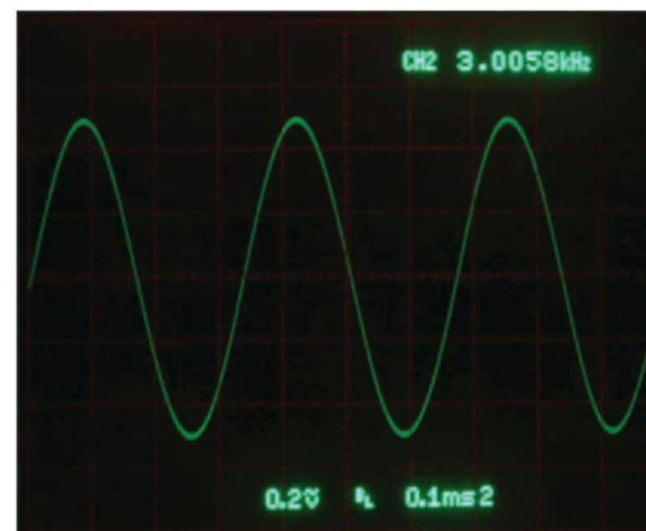


Figure 2: For the design used in Figure 1, we get a clean 3 kHz sine wave with a 110 mA load current.

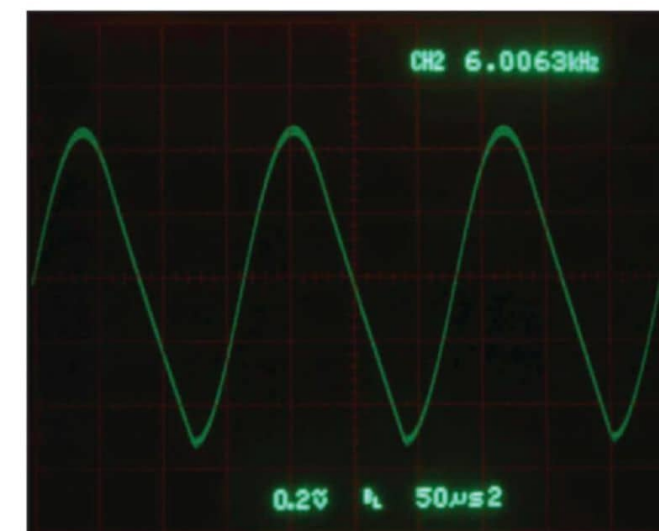


Figure 3: The same circuit shown in Figure 1 doesn’t sink enough current at 6 kHz, causing the sine wave to be distorted by slew rate limited discharge of C_{out} .

schematics around the web and also in commercial products!

To elaborate, an output capacitor is necessary for stability in Figure 1. As built, Figure 1’s test circuit is set for $V_{OUT} = 16 V_{DC} + 1 V_{PP}$ and 10 μF capacitor (not shown) across LOAD. Maximum current to discharge the 10 μF capacitor across LOAD is $16.5 V / 150 \Omega = 110 \text{ mA}$.

Assuming this is a constant current (it’s not, it decreases as V_{OUT} decreases), the maximum rate of change of a sine wave will be, using $i = C \times (dv/dt)$, $110 \text{ mA} / 10 \mu\text{F} = 11 \text{ V/ms}$. Plugging this into the formula for maximum rate of change of a sine wave $dv/dt = V_{pk} 2\pi f$ gives $f = 11 \times 103 / (0.5 \times 2 \times \pi) = 3501 \text{ Hz}$. Thus, the maximum clean sine wave we can get from this circuit is about 3500 Hz, as illustrated by the clean 3 kHz sine shown in **Figure 2** vs. the distorted 6 kHz sine shown in **Figure 3**.

To increase the negative discharge rate, you can increase the load current by decreasing load resistor. However, LOAD is already dissipating 1.7 W, so to have a load resistor that allows, for example, a 50 kHz sine wave means excessive power dissipation because the static current is about 25 A. While this initially appeared to be a good idea, it’s totally impractical.

So the next iteration had a source that could move positive and negative, using an LM3886 power op-amp as seen in Figure 3. A potentiometer sets the DC level and AC is injected from SP1. The nice thing about this circuit is that with a switch it can generate either a positive or negative signal for testing either polarity regulator.

It’s been years since I used that fixture and I don’t recall all the problems. The LM3886 has limited gain-bandwidth product (typically 8 MHz) and gain of 23 decreases fixture bandwidth to 350 kHz, which could

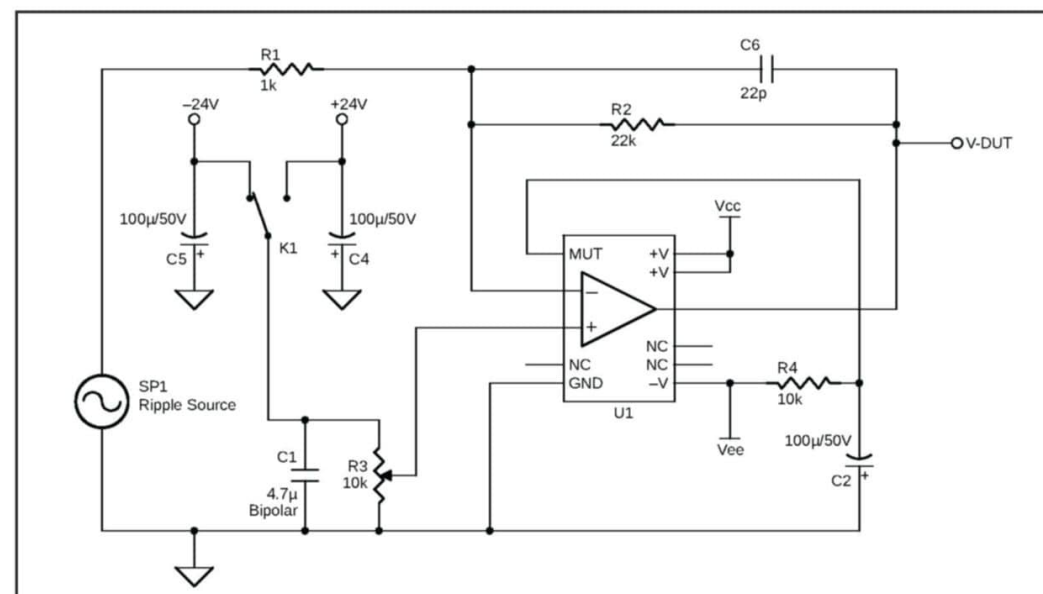


Figure 4: Here we have a ripple rejection DC+AC source using LM3886

Figure 5: Measurements with LM3886 fixture

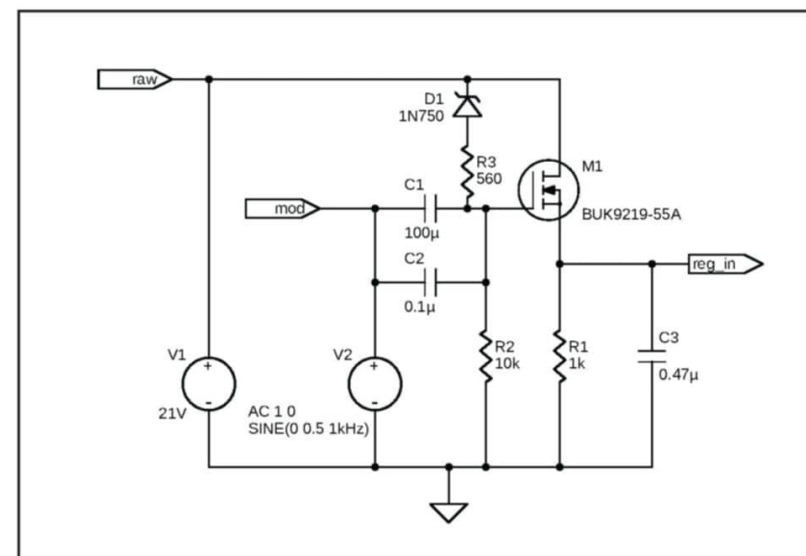
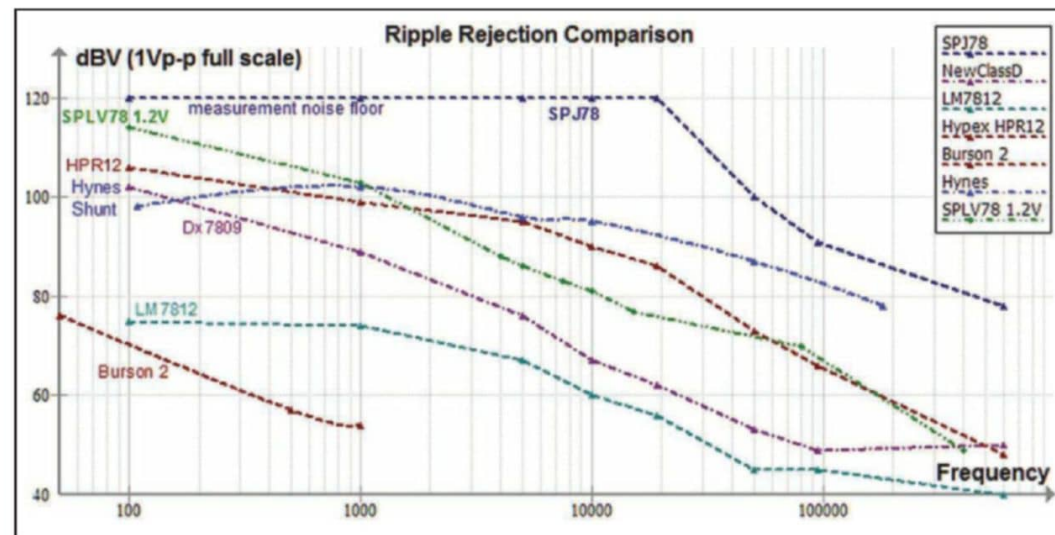


Figure 6: This schematic is for a ripple rejection passive summing DC+AC with the MOSFET

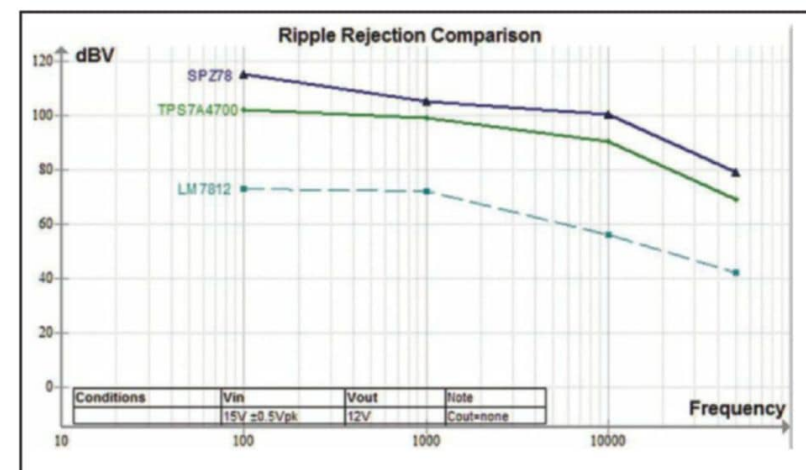


Figure 7: Measurements made with fixture discussed in Figure 6.

affect low level ripple amplitude measurements at 100 kHz (see **Figure 4**). There was significant feed-through as frequency increased, which may have been fixture layout or within the LM3886. It also suffered from overheating and stability problems, possibly due to poor design choices I made. There were other more global issues that I didn't even know about that we will examine later.

Figure 5 shows measurements made for some popular regulators of 2012. The numbers represent the ratio of peak input voltage to error voltage expressed as dBV. While measurements match their datasheets relatively well, they flattened at the ~120 dBV limit of a TiePie HS3 USB oscilloscope with a 16-bit 200 mV low-range spectrum analyzer. The unicorn is not in sight when the measurement is so far from an expected higher theoretical value based on the input isolation given by the "drain+collector only" connection to V_{in} (as seen in Figure 4 from Part 1 of the article). Keep in mind that 120 dBV here represents 1 μ V out of 1 V_p input ripple. Imagine a 1,000 m length of mostly clean string and you need to find the 1 dirty millimeter.

The passive source of **Figure 6** uses a Zener diode D1 to provide DC offset to a high current, low threshold MOSFET that delivers the signal to the regulator under test. An AC source is capacitively coupled to the gate to add modulation. It gave results similar to what was seen with the prior fixture, especially with higher error level such as the LM7812, but not as accurate at very low error values (see **Figure 7**). This has TPS7A4700 error as significantly better than its datasheet. It's probably a dual result of different measurement conditions (e.g., capacitors on the test device) and error from our measurement fixture. We found the TPS7A4700 to perform much better using a tantalum output capacitor than ceramic.

CLARITY. FLEXIBILITY. TRUE SOUND.



MODEL 426A14

2-IN-1 PHANTOM POWERED MICROPHONE PREAMPLIFIER

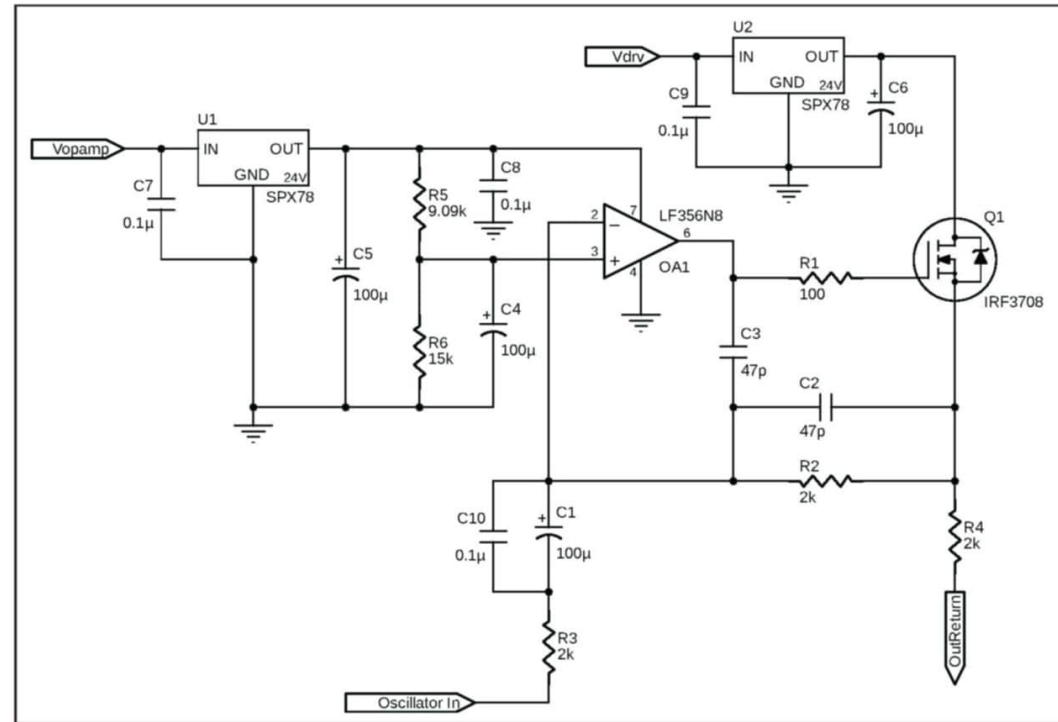
- 156 dB 1% THD and flat frequency response for high definition recording and modeling instruments
- Quickly change between 1/2" and 1/4" 0V, IEC 61094-4 compliant microphones
- Measure fast rise times and transients for superior impulse responses

PCB PIEZOTRONICS
MTS SYSTEMS CORPORATION

1 800 828 8840 | pcb.com/phantom

Visit **Booth D**
and see PCB's
patent pending,
48V microphone
system

Figure 8: This schematic is for an active buffer PSRR fixture designed and implemented in late 2018



About the Author

Brian Lowe is founder and principal engineer at Belleson LLC. His audio circuit design experience dates to 1971, when he designed a reverb unit using a ceramic phono cartridge, four ball point pen springs, a model car hub cap, a transistor amplifier kit, and a speaker. In the 1980s, he was author of an article in Issue 1 of *Glass Audio* called "A Self-Bias Servo for Push Pull Amps," and in 1984 he designed a diamond tester. He received US patent 8294440 in 2012 for a novel voltage regulator. He's a proud father of two thriving teenagers and spouse of a very tolerant and patient wife.

Project Files

To download additional material and files, visit <http://audioxpress.com/page/audioXpress-Supplementary-Material.html>

References

[1] J. Williams, A Closed-Loop, Wideband, 100 A Active Load: Brute Force Marries Controlled Speed," Linear Technology, Application Note 133, October 2011, www.analog.com/media/en/technical-documentation/application-notes/an133f.pdf

Resources

Belleson, LLC, <http://www.belleson.com>

"Belleson Superpower Regulator," diyAudio, www.diyaudio.com/forums/power-supplies/218837-belleson-superpower-regulator-heres-schematic-2.html.

J. Walton, "A comparative overview of power supply designs with listening tests," *Linear Audio*, Volume 4, September 2012.

Sources

Analog Discovery 2: 100 MS/S USB Oscilloscope, Logic Analyzer, and Variable Power Supply

Digilent | <https://store.digilentinc.com/analog-discovery-2-100msps-usb-oscilloscope-logic-analyzer-and-variable-power-supply>

Handyscope HS3 USB Oscilloscope

TiePie | www.tiepie.com/en/usb-oscilloscope/handyscope-hs3

In 2018, we updated our regulator's internal circuit to improve output impedance. With this change we also had to determine if any other performance characteristics were changed, for better or worse. Once again a decision was made to improve the power supply rejection ratio (PSRR) excitation circuit. This is an active version of the 2016 circuit, which puts a loop amplifier in control of its output and also sums the DC and AC parts of the signal (see **Figure 8**). It's similar to a circuit proposed by Jim Williams for a 100 A test of voltage regulation of digital loads.^[1]

Notice the output, as shown in **Figure 9**, is from a high current, low on-resistance IRF3708 N-channel MOSFET driven by a loop amplifier that monitors the voltage at the output node (source of IRF3708). The op-amp forces the output to follow the AC signal injected from "Oscillator IN" terminal through C1 || C10, offset with a portion of the DC voltage from VR2 as set by R5 and R6 (which are actually a trimpot). Regulator VR1 provides a separate power source for Q1 to isolate the op amp power supply from the output current. Also notice OutReturn in the lower right, which takes the output signal current directly back to the signal ground, avoiding any mix of output current with signal return current(s) from OA1. To be sure the layout is as clean as possible it was built on a custom PCB as seen in **Photo 1**.

Signal Generator

All the fixtures we've seen show an AC source input, what is that source? And what kind of measurement errors can it introduce? Some inexpensive and

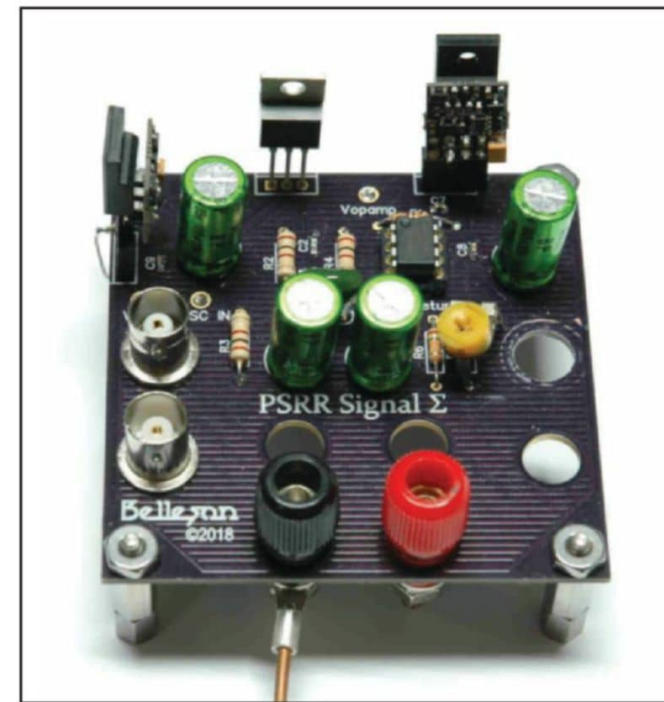


Photo 1: This is the PSRR active DC + AC signal summing fixture.

available sources have characteristics that make them better or worse for this measurement. As with the summing circuit, at these low levels of measurement every signal nuance is critical. There are many variables and a full discussion is too much to cover here! There is a supplemental web article with all the detail, and we'll present a summary of various issues here.

Several signal sources were examined, all relatively inexpensive and available through eBay or new from the manufacturer. Listed from oldest to newest, they are: the HP Model 200CD, the Wavetek Model 166, the TiePie HS3, and the Digilent Analog Discovery.

Problems introduced by these included, most prominently, signal feedthrough to either signal return (HP 200CD) or signal measurement (TiePie HS3). The HS3 also had minor noise pickup through the USB connection, even using a separately powered USB hub. Some spectra artifacts appeared to be higher frequency components that got aliased (or "demodulated") down into the measurement band. The AC power connection of the Wavetek had to be rearranged to prevent what could be called "hash" in the 80 kHz to 100 kHz range.

The Digilent has too much digitally induced noise and a significant DDS-induced skip in analog generator output for any sensitive measurement. The TiePie HS3 internal AWG, while very good, internally injects some of its generated signal into its own oscilloscope input. In an attempt to improve its performance, I decoupled the generator ground from the oscilloscope ground by using a band saw to cut the face plate between the generator and oscilloscope connectors, with no visible improvement. The performance of the TiePie AWG and HP200CD are exemplary, only not quite good enough for measurements of sub-microVolt ripple. Ultimately, the WaveTek 166 was the best signal source, but only if the AC plug has a ground isolator to disconnect its chassis from earth.

The Measurement Instrument

For the earlier analogy of finding a 1 mm smudge on a 1,000 m string, what do we use to find the smudge? A 4.5 digit multimeter

ACOUSTICS
- building your sound -

New Release

- Satori High End Coaxial •
- Constant directivity Waveguide version of SB26 softdome •
- Rohacell®/Carbon fibre sandwich cone series •
- A highly cost effective shallow 10" subwoofer •
- 8Ω version of the well-known 10" SB26NRX75-6 •
- and many more.....



VISIT US

HIGH END®
MAY 9-12, 2019 MUNICH
HALL 3 / J02

Engineered in Denmark Manufactured in Indonesia

Find Us on: **SBACOUSTICS**
info@sbacoustics.com

www.sbacoustics.com

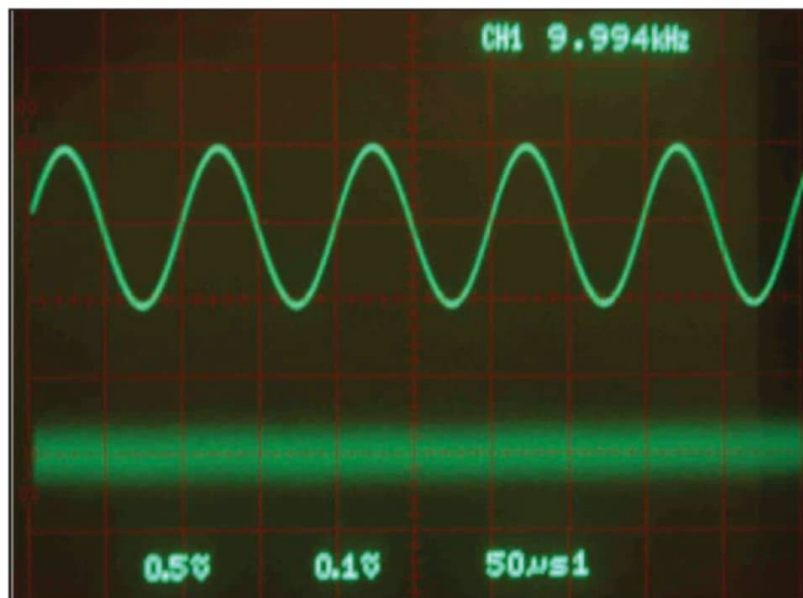


Figure 9: Here we see 1 V_{pp} AC at 10 kHz test signal from the summing fixture (top) and the regulator V_{out} (bottom)

should be accurate at DC, but even a true RMS meter has only limited accuracy as frequency increases. Interestingly, a RMS multimeter introduced an error signal in the spectrum analyzer at about 185 Hz, presumably the frequency of integration for the DVM.

With a 2 mV/div minimum range, an oscilloscope doesn't have the necessary resolution, although with the gain of 1000x amplifier some error can be visible. Given the grounding problems we discussed, even

having an oscilloscope powered during measurement affects the spectra we're viewing. Of course, it depends on the oscilloscope. I typically use a 150 MHz bandwidth analog oscilloscope with linear supplies that uses lots of AC power and transmits some garbage back into the grid.

The usual instrument of choice is a spectrum analyzer. In 1985, when John Roberts wrote his article about the Preeminent Preamp, a spectrum analyzer was tens of thousands of US dollars, but today good ones are affordable as PC-based instruments and, for low frequency, even a computer sound card can be a decent spectrum analyzer with free or inexpensive software.

The TiePie Handyscope HS3 has been a fixture at the Belleson test bench for many years. It has a great software interface with lots of functionality and mathematical analysis tools such as FFT, averaging, integration, statistical functions, and so forth. The hardware has multiple sample rates and digitizer resolutions that are software selectable, including a 16-bit resolution, ± 200 mV full-scale range with AC coupling that's very useful in our PSRR measurements. It has two-channel input and the previously discussed AWG. There are some limitations to its measurements such as one channel slightly better than the other and some low level internal signal coupling from the AWG, when it's active. It was used for all the FFT spectra in this article.

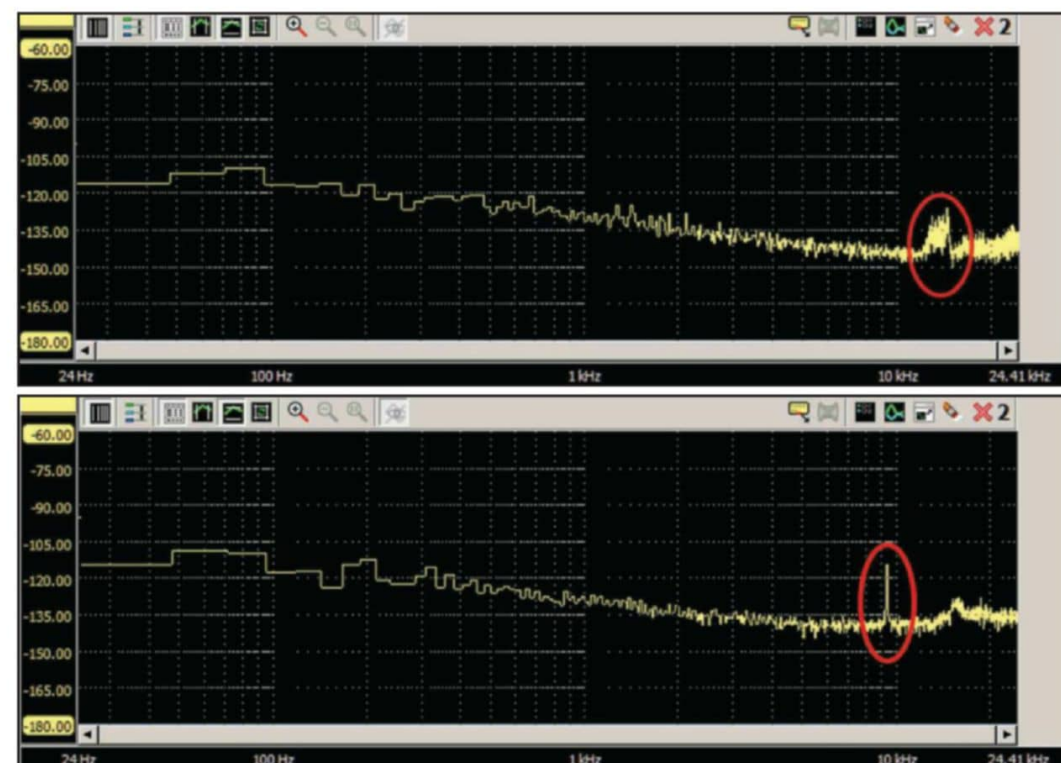


Figure 10: The fluorescent light adds hash around 27 kHz.

Figure 11: This shows the spectrum of a commercial DC power supply.

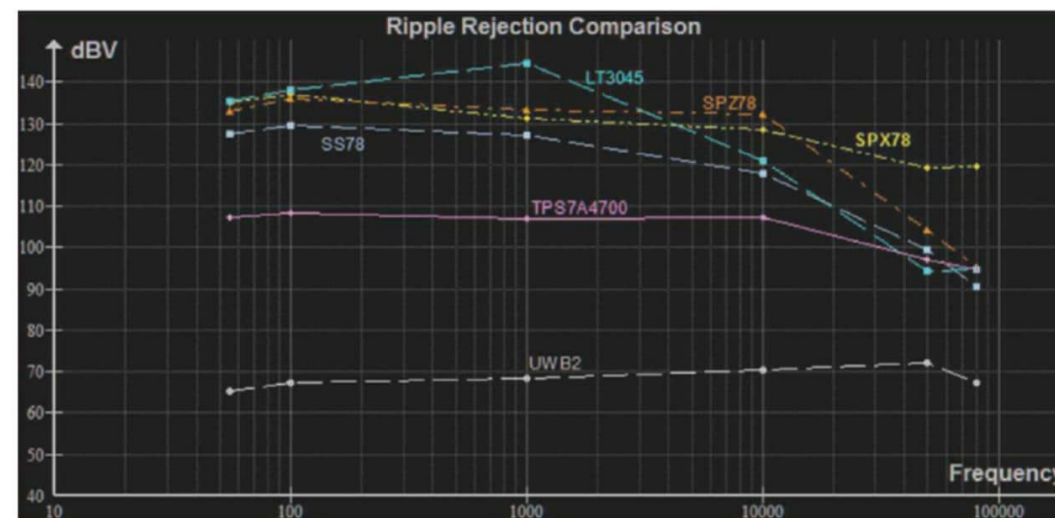


Figure 12: Any unicorns hiding here?

Increased Measurement Resolution

The digitizer resolution of 16 bits at 200 mV full scale gives a maximum resolution of 3 μ V ($0.2/2^{16}$), certainly not 10 times better than the ~ 100 nV ripple ($0.5/10^{135/20}$) we're attempting to measure. To sidestep this limitation, we use a 1000x amplifier to boost the low-level signal and increase the resolution to 3 nV.

The amplifier was originally built as a noise booster and, while there's not enough editorial space for a full discussion, one important element is to design the booster with "wide enough" bandwidth to not

attenuate the measured signal at either the low or high ends of the desired measurement frequency range.

What Else Can Go Wrong?

The op-amp shown in Figure 8 was originally an LF356, a fast settling high-performance JFET input op-amp from the 1980s. At some point in the analysis using the 2018 fixture, some weird artifacts were showing in the spectrum and replacing that LF356 with a low distortion LME49710 fixed it. Alas, I didn't

The Electrostatic Speaker Design Cookbook
is a complete guide for the novice and the experienced builder to successfully build this unusual sound reproduction device.

THE ELECTROSTATIC LOUDSPEAKER DESIGN COOKBOOK
by ROGER R. SANDERS
With a Circuit Guide by Barry McCune

cc-webshop.com

SpiralAir™
Interconnects

Coax
Is Cool
Again!

Cardas Golden Strand
Air Filled Cotton Dielectric
Unique Spiral Litz Shield
ETI Tellurium Copper Connectors

Affordable Litz Interconnects and Bulk Wire
Tonearm - Phono - Line - Loudspeaker

KAB
Preserving The Sounds
Of A Lifetime

www.kabusa.com

take any photos and can't reproduce it now, so I can't say if it was real or something else was happening.

Another semi-obvious problem can be fluorescent lights. **Figure 10** shows a spectrum of what happens when the light over my workbench is on.

Then there's the raw DC supply we didn't even discuss. All the measurements shown up to now use a custom built raw linear supply regulated by (what else?) our own high-performance regulators. **Figure 11** shows a noise floor from the test fixture when powered by an inexpensive supposedly linear supply. Note that the AC input to the test fixture is shorted to zero volts with three 50 Ω BNC terminators.

There is more low frequency noise and a spike just above 9 kHz from the internal control circuit of the power supply. Again there's no good way to know if this is actually a 9 kHz component or if it's been

aliased from some higher frequency by the digitizer.

The Search Continues

With a custom test fixture, a low noise wide bandwidth 1000x amplifier, a clean signal source, a sensitive digitizing oscilloscope with FFT spectral conversion, all instruments plugged into the correct outlets, and a new moon just over the horizon, sometimes measurements can be made to show how good the latest modern regulators can be (see **Figure 12**).

While ripple rejection is only one indicator of regulation quality, it's an important one. Yet output impedance, transient load response and noise (and maybe even harmonic distortion??) are also important. Also, these measurements are made with no load. Thus, while there are unicorn footprints all around, the search continues.

Measuring Super Regulators

By **Jan Didden**

(audioXpress, Technical Editor)

Super Regulators have interested me, ever since I published my first article on the subject in *The Audio Amateur* (the predecessor to audioXpress) in 1987. And later, in 1994, I was invited by Walt Jung to work on his classic four-part series for *The Audio Amateur* (<https://linearaudio.nl/superregs>).

And if anything comes out of Brian Lowe's articles, it is the realization that at this level of performance, everything matters, and measurement becomes as hard and tricky as the design itself. Lowe's perseverance in this is commendable.

A few comments. In Part 1 of Lowe's article series (audioXpress, May 2019), he shows a oscilloscope shot of a super regulator oscillating with an AD797 as an error amp. Both Walt Jung and myself, and many others, have repeatedly stated that the AD797, while being a superb audio op-amp, is NOT the preferred op-amp for a super regulator. (I often use an AD825 but there are many others that are well-suited). The op-amp selection criteria have been documented extensively.

He also mentions that the super regulator would have start-up issues. I can assure Lowe and the readers that literally many hundreds of super regulators have been built, providing clean and stable supply voltages with no trace of oscillations or startup issues. But

you need to read relevant articles and make informed design choices. The Resources and References listed at the end of Part 2 of Lowe's article are a good start, and many are available for free download.

The schematics don't always show an output cap on the regulator in the schematic. Lowe does mention it in passing, but it is important enough to emphasize: a regulator output cap is critical for regulator stability. But: The requirement is for a lossy electrolytic capacitor with some non-zero equivalent series resistance (ESR), and specifically NOT a high-quality film cap! This capacitor has only a minor effect on the output impedance, being in parallel with the already very low impedance of the regulator itself. But it modifies the loop transfer to assure stability. Most datasheets for regulators specify a range of allowed ESR for the output cap.

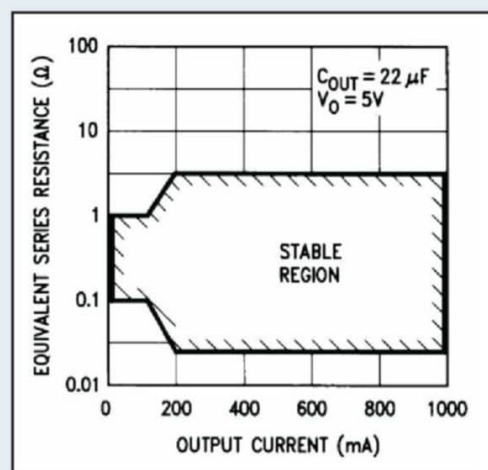


Figure 1: Most datasheets for regulators specify a range of allowed ESR (e.g., this one for the LM2941).

Figure 1 for the LM2941 is illustrative. Super regulators are no different in this respect. The power supply rejection ratio (PSRR) test circuits show an output cap of 0.1 μ F on the driver. Companies such as Texas Instruments advise against using an output capacitor here, on the grounds that it may impact the measurement as the capacitance can interact with the capacitive and/or inductive part of the device under test (DUT) input impedance; it adds an uncertainty to the measurement results.

For readers interested in other measurements on super regulators beyond PSRR I can recommend Jack Walton's article mentioned in the Resources section of the article.

Engineering Consulting for the Audio Community

Celebrating
36 YEARS
1983-2019

MENLO SCIENTIFIC

- Liaison Between Materials, Suppliers, & Audio Manufacturers
- Technical Support for Headset, Mic, Speaker & Manufacturers
- Product Development
- Test & Measurement Instrumentation
- Sourcing Guidance

MENLO
SCIENTIFIC

USA • tel 510.758.9014 • Michael Klasco • info@menloscientific.com • www.menloscientific.com

More About Noise in Vacuum Tube Circuits

In the March 2019 issue of *audioXpress*, we examined noise in vacuum tube circuits. Subsequently, reader Burkhard Vogel informed the author of errors in that article, as discussed in an Article Update page in the May issue of *audioXpress*. Vogel also mentioned two other issues concerning vacuum-tube noise, but these required more space than was available in the May issue. Thus, these issues are the topic of this article.

By
Richard Honeycutt
(United States)

The first of these issues is flicker noise. As discussed in the March 2019 Hollow-State Electronics article, flicker noise is similar to shot noise in that both are caused by fluctuations in the electron flow in a circuit element. Both shot noise and flicker noise

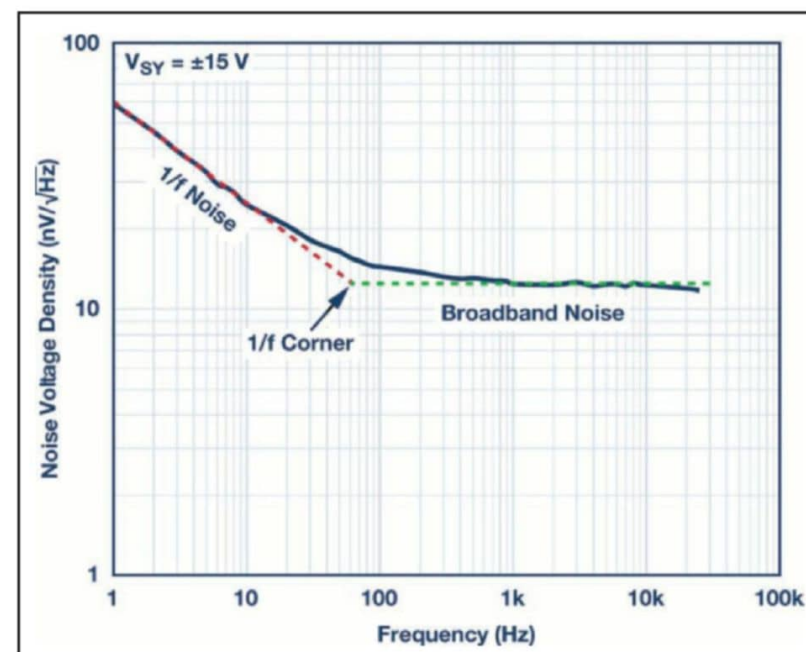


Figure 1: The low-frequency noise has a 1/f spectrum.

have Gaussian amplitude distributions. However, shot noise produces a sound described as “like lead shot hitting a tin roof,” whereas flicker noise sounds more like a flickering flame. Another difference is that shot noise has a white spectrum—equal energy per Hertz—but flicker noise has a 1/f spectrum (see **Figure 1**).

The 1/f spectrum is not unique to electrical noise, but seems to be a ubiquitous phenomenon, having been observed in music, biology, and even economics.^[1] **Figure 2** shows the waveform of 0.1-to-10-Hz flicker noise of a low-noise IC.^[2]

Early studies of flicker noise led experimenters to believe it was caused by variations in emission at different places on the cathode. G. L. Pearson’s measurements showed that both flicker noise and shot noise are decreased as the condition of space-charge saturation is approached, with the change in flicker noise occurring most rapidly. If the grid is biased positively, the resulting grid current will increase both shot and flicker noise. Some writers have stated that in space-charge saturation, neither flicker noise nor shot noise is significant in vacuum triodes: thermal noise dominates. Others have stated the opposite.

Space-charge density depends not only on the electron emission from the cathode, but also the plate current, as the latter removes electrons from the space charge. Two examples are instructive.

The “Must Have” reference for
loudspeaker engineering professionals.

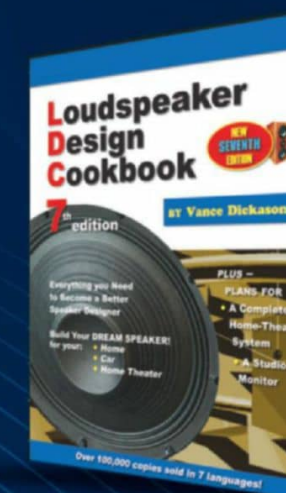
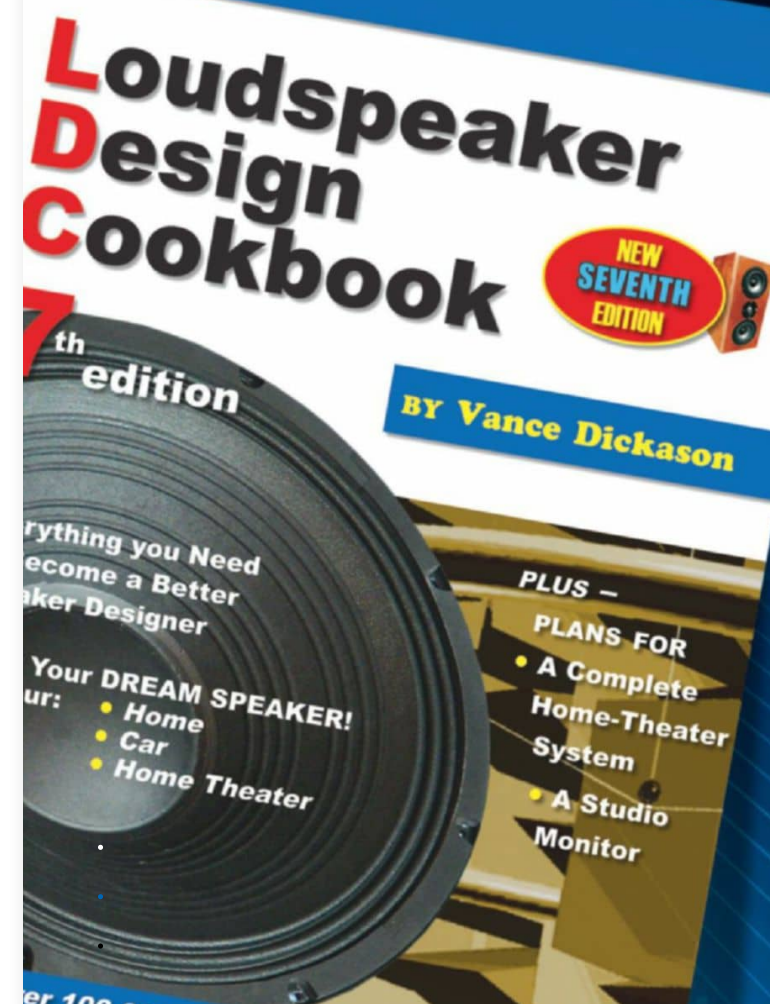
Home, Car, or Home Theater!

Back and better than ever, this 7th edition provides everything you need to become a better speaker designer. If you still have a 3rd, 4th, 5th or even the 6th edition of the *Loudspeaker Design Cookbook*, you are missing out on a tremendous amount of new and important information!

Now including: Klippel analysis of drivers, a chapter on loudspeaker voicing, advice on testing and crossover changes, and so much more! Ships complete with bonus CD containing over 100 additional figures and a full set of loudspeaker design tools.

A \$99 value!
Yours today for just \$39.95.

Shop for this book, and many other audio products, at
www.cc-webshop.com.



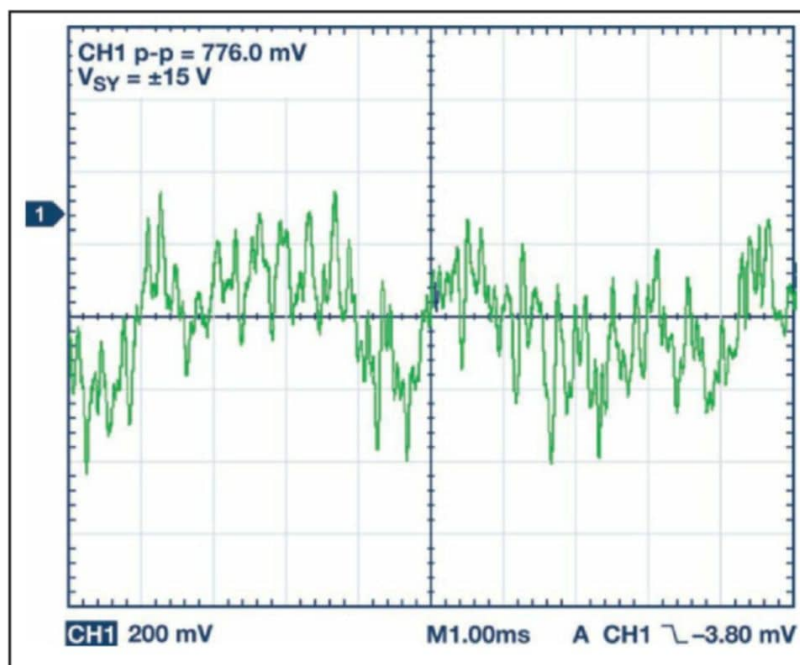


Figure 2: Flicker noise in an IC

The original Western Electric Model 47 capacitor mic operated from a battery supply that provided 1 V for the filament of the impedance-translator tube. It was found that noise was lessened if a 1.5 V filament supply was used. This would have been the natural result of the higher voltage increasing the space charge toward a condition of saturation.

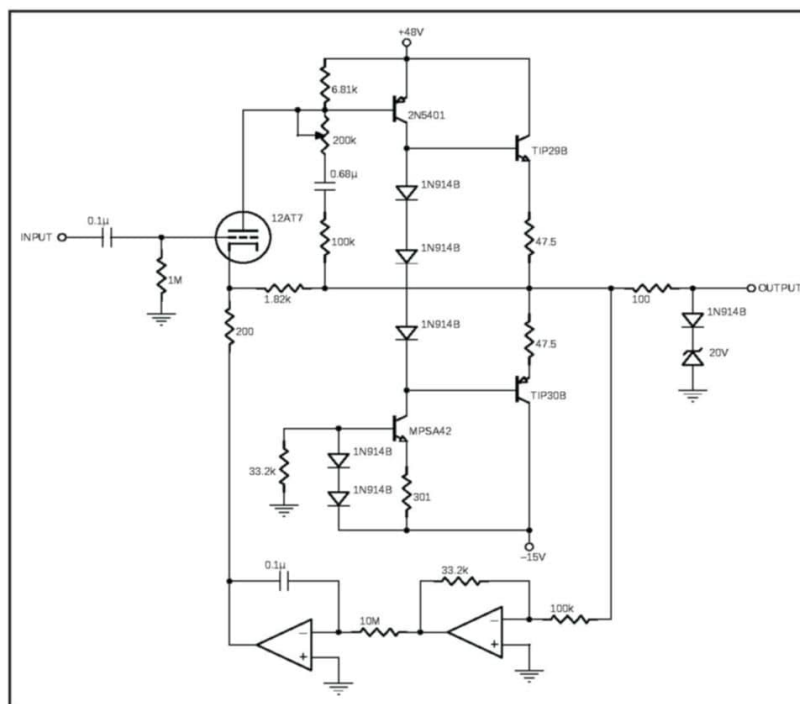


Figure 3: The schematic diagram of the RPA amplifier

In 1995, Donn Werrbach of Apex Systems was awarded a patent^[3] for the “Reflected Plate Amplifier.” The basic circuit of the RPA is shown in **Figure 3**. A 12AT7 tube is used as the gain stage, but in an unusual way. Most tube amplifiers are classed as Voltage-Controlled Voltage Sources (VCVS), since the control-grid signal voltage is used to control the output voltage of the stage. However, fundamentally, a tube is a Voltage-Controlled Current Source (VCCS); the control-grid voltage controls the plate current of the tube. In most amplifiers, the plate current flows in the plate resistor, producing a voltage drop that is the output voltage.

In the RPA, rather than using a plate resistor, the very small plate current (<1 mA) of the triode feeds a current mirror, which is a Current-Controlled Current Source (CCCS). The input impedance of a CCCS is essentially zero ohms (0Ω), so the voltage gain of the triode is also essentially zero, negating the Miller effect. The output current signal is fed to a full-complementary-symmetry bipolar transistor output stage that provides a low-impedance voltage-source output for the RPA.

The RPA provides several other advantages compared to a conventional common-cathode circuit. By operating at such a low plate current, it can use the low-current +48 V phantom supply for B+. Also, the very low plate current demands less cathode emission, so the filament can operate from 12 V rather than the usual 12.6 V, reducing filament current and temperature, as well as shot noise, which increases with filament temperature. (An RPA stage is 10 to 20 dB less noisy than a conventional tube preamp stage.)

Note that the lower shot noise is caused by decreased production of the current impulses, rather than by the averaging effect of space-charge saturation. However, the extremely low plate current allows space-charge saturation to occur, reducing the effect of the shot noise. So the Western Electric circuit output contained less shot and flicker noise when filament voltage was increased, moving the tube toward space-charge saturation. In contrast, the RPA produced less shot noise when the filament voltage was decreased, because the low plate current allowed space-charge saturation to be maintained even with fewer electrons being emitted from the cathode.

There has been much research attempting to obtain an equation to predict flicker noise in a vacuum tube, and since the results depend upon the cathode material as well as the degree of space-charge saturation, no single equation has emerged. Aldert Van Der Ziel has detailed a variety of theoretical approaches leading to several different equations.^[4]

Vogel has taken a different approach. Any device having both thermal and $1/f$ noise will have a “noise corner frequency f_c ” where the two types of noise are equal (see **Figure 4**). Thus below f_c , $1/f$ noise dominates, and above f_c , thermal noise is predominant. Therefore, since we have an equation to predict thermal noise for a particular tube, if we knew the value of f_c , we could predict the noise in $nV/\sqrt{Hz}$ in any frequency range. Vogel’s very detailed article^[5] presents his findings, including curves showing the measured noise spectra of actual circuits. He found that the spectrum is not always $1/f$ (10 dB/decade) but can often be $1/f^2$ (20 dB/decade). Vogel references Telefunken as saying that f_c is often about 10 kHz for audio tubes, but he then proceeds to show measurements indicating a significant range of values for f_c .

Curiosity drove me to build a triode circuit using a NOS 6SL7GT and measure the noise. The circuit is shown in **Figure 5**. The first stage is a typical common-cathode amplifier, and the second stage is a cathode follower to allow measurements without loading. All carbon (composition and film) resistors and metal film resistors produce flicker noise, but

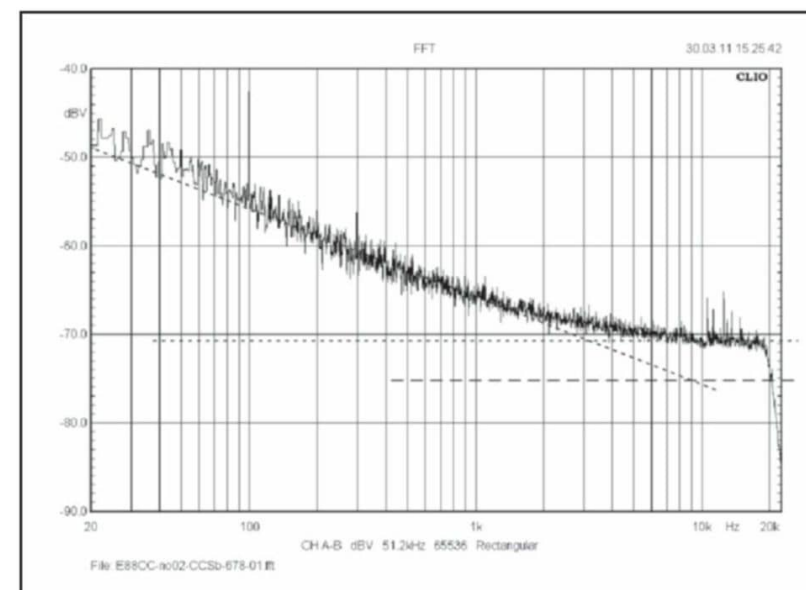


Figure 4: Defining the noise corner frequency f_c (from *How to Gain Gain*, 2nd edition, by Burkhard Vogel, Springer Nature, 2013)

ALL ELECTRONICS

C O R P O R A T I O N

Thousands of Electronic Parts Available Today!

LEDs · CONNECTORS · RELAYS
 SOLENOIDS · FANS · ENCLOSURES
 MOTORS · WHEELS · MAGNETS
 PC BOARDS · POWER SUPPLIES
 SWITCHES · LIGHTS · BATTERIES
 and many more items...

We have what you need for your next project.




www.allelectronics.com
 Discount Prices · Fast Shipping

**Ready, willing
and
Avel**

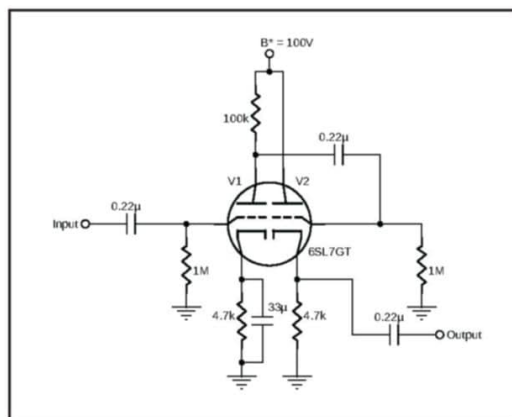


***offering an extensive range of ready-to-go
toroidal transformers
to please the ear, but won't take you for a ride.***

.....

 **Avel Lindberg Inc.**
47 South End Plaza, New Milford, CT 06776
p: 860.355.4711 / f: 860.354.8597
sales@avellindberg.com • www.avellindberg.com

Figure 5: Test stage for noise



metal-film resistors produce less shot noise, so these were used for R_p and R_G . (Actually, the input was shorted to ground during the measurement, so R_G would not have contributed any noise.) A difficulty with evaluating noise measurements in some of the older papers is not knowing what type of resistors were used.

Figure 6 shows the measured noise spectrum. (The input impedance of the measuring instrument was 10 kΩ: high enough to prevent low-frequency attenuation by the output capacitor.) The spikes in the noise waveform are line noise (hum) from the power supply, which was a half-wave rectifier feeding a three-stage RC filter. Some inductively-coupled noise and/or ground noise may also have contributed. But ignoring the spikes, we see an almost flat spectrum extending downward from the ~20-kHz cut-off of the measuring instrument to about 100 Hz.

Looking very carefully, you can see an increase in noise as frequency decreases across the whole band, with about an 8 dB/decade slope. This indicates flicker noise with a corner frequency >20 kHz. (The

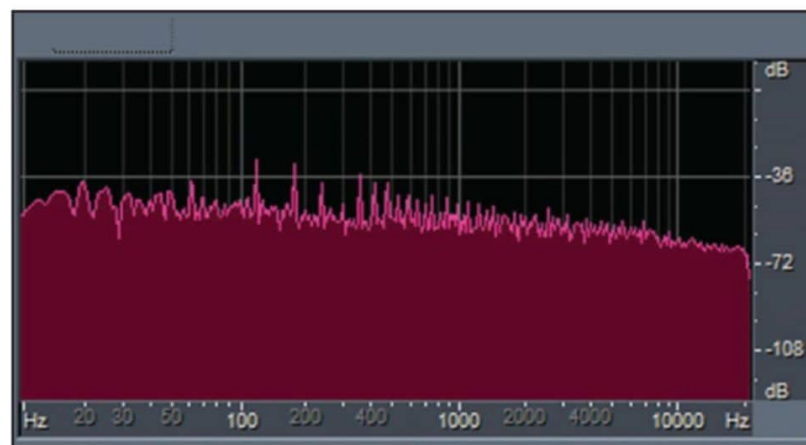


Figure 6: Measured noise from the 6SL7GT test circuit

absolute voltage of the measured noise was not considered important, since I was only looking for the spectrum shape.) The high value of f_c falls within the range 100 Hz to 60 kHz that Vogel reports having measured.[6]

Grid Resistor in a Phono Preamp

The other issue raised in Vogel's comments to me was the effect of the first-stage grid resistor, which typically has a value of 47 kΩ in a preamp designed for moving-magnet cartridges. I referred to the effect as "tiny." I based my statement on the thermal (white) noise generated by the resistor in parallel with the resistance of the cartridge (~1.5 kΩ).

Vogel points out that the cartridge inductance (~0.5H), the above-mentioned resistance, and a 250 pF loading capacitor combine to produce a significant frequency-dependent boost that can raise the noise voltage to between 20 and 40 nV/√Hz between 10 and 20 kHz.

Other Noise Considerations

Some manufacturers have marketed "low-noise" tubes. What, exactly, can be done in the manufacture of a tube to reduce noise production? One factor is transconductance g_m : increasing g_m increases both the noise voltage and f_c . This leads to complex considerations, since g_m , r_p , and μ are interrelated by the equation $g_m = \mu/r_p$, so changing g_m will change the gain of the circuit. By increasing gain, increasing g_m increases both the gain stage's output noise voltage and f_c ; however, it decreases the input referred noise voltage of the gain stage, because the noise resistance decreases. Cathode material can have an effect on flicker noise and shot noise, but tubes of a given type all have the same cathode material. The most effective way for a manufacturer to supply a truly low-noise tube is to test regular-production units for noise levels and select the best ones. In this way, those tubes with less perfect vacuums—hence, higher shot noise—will be eliminated.

The effect of resistor type on noise has already been discussed. Wirewound resistors are the quietest for audio use, but they do have a small inductance, are expensive, and are not always available in all values. But even wirewound resistors will generate Johnson noise, and the hotter they run, the more noise they will generate. Operating resistors well under their rated power helps keep them cool.

Heating a resistor up from 25°C to 100°C will increase its thermal noise by about 1 dB. While this is not a lot, a resistor dissipating excessive power can operate well above 100°C, and the increased noise

can become an issue. Test equipment that must have extremely low noise levels should not be mounted at the top of equipment racks where the heat accumulates, and in some lab applications, low-noise amplifiers are actually refrigerated to keep noise down. This, of course, would be rather extreme for an audio system! For more useful information on resistor noise see Resources.

You may have noticed that the AC-line-related frequency components in Figure 6 were well above the random-noise level. This is not an unusual condition for inexpensive consumer tube electronic devices. In order to save time, I built the test amplifier on a used chassis that I had in my junk box, and it already had a power supply incorporating a half-wave selenium rectifier and a three-stage RC filter. I replaced the old filter capacitor with one not so old (but still not new), and when I wired the test amplifier, I made sure to run all ground connections to the ground side of the input connector so as to avoid creating common grounding impedances. Or I should say, "almost all ground connections," because the chassis already had an output connector that was grounded to the chassis some inches away from the input connector. It was not as bad as the 1950s TV sets, in which can-type filter capacitors were grounded pretty much all over the chassis. But the line-noise levels certainly could have been improved. In building a serious project, it helps to keep the above noise considerations in mind. ☒

References

- [1] W. H. Press, "Flicker Noises in Astronomy and Elsewhere," Comments in *Astrophysics*, 1978.
- [2] R. Kiely, "Understanding and Eliminating 1/f Noise," *Analog Dialogue*, Volume 51, May 2017, www.analog.com/en/analog-dialogue/articles/understanding-and-eliminating-1-f-noise.html.
- [3] "Reflected Plate Amplifier," US Patent # 5,450,034, Aphex Systems, Ltd., July 1994.
- [4] A. Van Der Ziel, "Flicker Noise in Electronic Devices," *Advances in Electronics and Electron Physics*, Volume 49, pp. 34-249, Academic Press, 1979.
- [5] B. Vogel, "The Glowing NoiseMaker - On the demystification of triode noise," *Linear Audio*, Volume 4, September 2012.
- [6] Vogel, *ibid*

Resources

Y. Hernik, "Selecting Resistors for Pre-Amp, Amplifier, and Other High-End Audio Applications," Vishay Precision Group, January, 2011, www.vishaypg.com/docs/49997/49997.pdf.

Fusion Amp

- High-End DSP controlled Plate Amplifiers
- Using industry leading NCore® technology
- Selectable presets and filters
- Multiple versions available

info: www.hypex.nl

contact: sales@hypex.nl

Here are a few places where you might find a copy of *audioXpress* and possibly meet one of our authors and staff members.

June 8–14, 2019
InfoComm 2019

Conference: June 8–14 | Exhibits: June 12–14
Orange County Convention Center, Orlando, FL
www.infocommshow.org

InfoComm 2019 will be in Orlando, FL, this year. InfoComm is now consolidated as the largest pro-AV show in North America, representing every facet of audiovisual technology with 44,000 attendees and 1,000 exhibitors expected for the 2019 edition. From the largest professional audio expo, largest digital signage expo, largest collaborative conferencing expo, plus the hottest products, emerging trends and top-notch professional development, all is ready for another exciting edition.

InfoComm 2019 will add new exciting topics for discussion and new themed areas. The event kicks off with the traditional Opening Reception on Tuesday, June 11, from 7 to 9:00 P.M. at the B.B. King Blues Club, sponsored by Samsung, Blackmagic Design, and Crestron. Wednesday, June 12, there's the Tech Managers Forum and Reception, and the next day there's also the Live Events Forum and Reception. Both events take place at the Orange County Convention Center.

As the most important show in North America for professional audio, unified communications and collaboration, display, video, control, digital signage, building automation, security, and live events, there are conference tracks and specific events targeting every one of those applications, always from the perspective of installation and systems integration. The 2019 edition will explore the fast-growing markets for audiovisual solutions in hospitality and retail. The show will host more than 30 education sessions focused on the ways that companies in hospitality and retail and the AV solution providers that serve them are using AV technologies to bring efficiency, entertainment, and personalization to the customer experience.

June 9–10, 2019
ALMA International Symposium and Expo (AISE) 2019

Orange County Convention Center, Orlando, FL
<https://almaint.org>

The Association of Loudspeaker Manufacturing & Acoustics (ALMA) International will promote its ALMA International Symposium & Expo (AISE) June 9–10, 2019, just prior to and in affiliation with InfoComm in Orlando, FL. AISE 2019 takes place at the DoubleTree by Hilton Universal in Orlando. Attendees can expect ALMA's acclaimed technical and business content with more than 30 hours of education in two packed days along with exhibitors and attendees from around the world. The event will be a unique opportunity to expand the scope of ALMA's activities, bringing loudspeaker industry members together. ALMA has been working hard for AISE 2019 and confirmed activities including the first Speaker Builders Workshop (SBW), a full-day, hands-on, interactive workshop on June 10. Sponsors and presenters include COMSOL, Eminence, Hernon, Audio Precision, and Klippel. SBW will be groundbreaking in its scope and presentation. Be sure to sign up early as seating will be limited.

The floor layout is designed to promote a flow of visitors to the exhibits at all moments, directly accessing the three breakout session rooms. Sessions include discussion panels, seminars, papers and product/technology showcases. Visit the ALMA website for full details of the confirmed sessions and schedule.



June 11–13
CES Asia

Shanghai, China
www.cesasia.cn

CES Asia 2019 will return to Shanghai, China, as the only consumer electronics industry event focused on the Asia-Pacific, taking place at the Shanghai New International Expo Centre (SNIEC) and the Kerry Hotel in Pudong New Area.

The annual show is growing every year. CES Asia 2018 brought together more than 500 companies from around the world to share transformative technology with a large focus on Augmented Reality (AR), 5G Connectivity, and Vehicle Technology. The show is owned and produced by the International CES (Shanghai) Exhibition Co., Ltd., which is a wholly foreign-owned enterprise by the Consumer Technology Association (CTA), and is co-produced by Shanghai Intex Exhibition Co., Ltd. (Shanghai Intex), a leading producer of international trade shows in China. Special co-organizers for CES Asia are the China Chamber of Commerce for Import and Export of Machinery and Electronic Products (CCCME) and the China Electronic Chamber of Commerce (CECC). Since 2016, CES Asia has been granted for the Trade Fair Certification by the United States Department of Commerce (USDOC), designed to increase US exports and involvement of US companies in international trade shows.



June 18–20
2019 AES International Conference on Audio Forensics

Holiday Inn Porto-Gaia, Porto, Portugal
<http://www.aes.org/conferences/2019/forensics>

The Audio Engineering Society (AES) International Conference on Audio Forensics is dedicated to exploring advances in the field of Audio Forensics by providing a platform for research related to the forensic application of speech/signal processing, acoustical analyses, audio authentication, and the examination of methodologies and best practices.

This is the seventh AES conference devoted to the technical developments and practical approaches developing in the field of Audio Forensics. With increased participation at each offering, this conference is the hub for researchers and practitioners to exchange ideas and foster new approaches to address problems that are evolving every day. The conference program is now available and includes a keynote by Karlheinz Brandenburg, Fraunhofer Institute for Digital Media Technology, Ilmenau, Germany, and tutorials on Automatic Speaker Recognition and Deep Learning for Audio Synthesis, Separation, and Enhancement.



June 22–23
CanJam SoCal

Irvine Marriott, Orange County, CA
<https://canjamglobal.com/shows/socal2019>

This year happening in June, CanJam SoCal 2019 is heading south to the beautifully remodeled Irvine Marriott in the heart of Orange County. Featuring more than 100 leading brands in over 25,000 ft² of exhibition space, CanJam SoCal 2018 will showcase the latest products and innovations in headphones and personal audio electronics in all price ranges. The venue is located within miles of some of Southern California's most amazing beaches, professional sporting events, and fabulous shopping. Closest to John Wayne Airport, the venue is also easily accessible from LAX, Long Beach Airport, and San Diego International Airport.



ELECTRONIC TRANSFORMERS

- Original Equipment
- Replacement
- Amateur

TRIAD MAGNETICS, INCORPORATED

460 HARLEY KNOX BLVD., PERRIS, CA 92571

www.TriadMagnetics.com



Solstice
MLTL Reference
Tower Speaker Kit



Blast Box
200 Watt Portable
Bluetooth Speaker Kit



C-Note
MT Bookshelf
Speaker Kit Pair



Dayton Audio
18" Ultimax Subwoofer
and Cabinet Bundle



Powered Dayton Audio
10" 500 Watt Subwoofer Kit
with Dual Passive Radiators
and Built-in DSP

Speaker Kits for Every Skill Level



Epique CBT24K
Line Array Speaker Kit Pair

Parts Express offers the largest variety of speaker kits for all skill levels, from beginner to expert. Whether you are looking for a large line array like the Epique CBT24K or a portable Bluetooth speaker like the Blast Box, Parts Express has a kit perfect for you.

CBT24K and CBT36 are licensed under U.S. patent number 7,684,574 and 7,826,622 from Harman Intl Ind, Inc.

Custom OEM inquiries welcome.

**SAVE \$15
off \$150 order!**

Code: 6AX2019
Expires 7/31/2019

Not valid with any other offer, on prior purchases or backorders.
Not valid on Commercial Sales accounts. No cash value.
Valid for one time use.



parts-express.com
1-800-338-0531