1940

Walt Disney's *Fantasia* is released, with eight-track stereophonic sound.

1941

In 1941 E.H. Scott publishes a landmark article entitled "Scott High-Fidelity Receivers" in the June issue of the *IRE Proceedings*. Scott calls for a frequency response that is "flat between 30 and 10,000 cycles." He also declares that "15 to 25 watts with very low distortion" is now required of an amp/speaker combination. His Phantom Deluxe receiver is offered as proof of concept. It includes an FM radio and a power amp using a pair of 6L6 tubes in push-pull.

Commercial FM broadcasting begins in the U.S.

1942

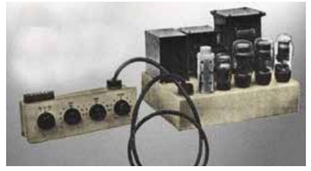
The first stereo tape recordings are made by Helmut Kruger at German Radio in Berlin.

Bell Labs publishes its standards for high fidelity in the *IRE Proceedings* based on three decades of hearing research led by Harvey Fletcher.

1945

Fisher Radio Co. is founded by Avery Fisher.

In September 1945 H.J. Leak & Co. Ltd. of London releases the first of its "Point One" series amplifiers, so named because the total harmonic distortion is 0.1% at rated output. This represents a major leap forward in accepted standards for high-performance amplifiers (with 2% distortion generally considered acceptable at the time). This first "Point One" amplifier is known as the Type 15, and produces 15W at 0.1% midband distortion, using push-pull KT66 valves connected as triodes, with 26dB feedback applied over four stages.



The 6SN7 tube debuts.

1946

Sony (then known as Tokyo Telecommunications Engineering Corporation) is established in Nihonbashi, Tokyo. The Sony name is created by combining "sonus," the Latin for "sonic," with "sonny," denoting small size or youthful boy. The name is chosen for its simple pronunciation, which is the same in any language. Sony becomes one of the greatest innovators in audio and video electronics, quickly establishing a reputation for brilliant engineering and manufacture.

A group of Japanese businessmen start the Kasuga Radio Company in Nagano with the goal of developing a line of radio equipment. (Kasuga will change its name to Trio in 1960 and to Kenwood Electronics in 1986.)

1947

The Williamson "high quality amplifier" circuit is published by D.T.N. Williamson in *Wireless World*. For about two years, the Williamson amplifier exists purely in schematic form, so if you want one, you have to build it from scratch. As it turns out, the American military has trained hordes of electronics technicians during WWII. That, and the pent-up demand for recreation following the war, turns DIY audio into a national pastime. Riding as it does on the thirteen-year wave of the *Wireless World* quality amplifier project, Williamson's circuit enjoys unprecedented momentum in the marketplace. Williamson's amplifier is a symmetric push-pull design that uses global negative feedback and a specially designed output transformer to produce lower levels of distortion than previous designs (less than 0.1% midband THD at full rated power). The original output stage uses triode-connected KT66 tetrodes.

The Heath Company (originally founded in 1912 as an aircraft manufacturer) introduces its first electronic kit—the O1 oscilloscope ($50). The company goes on to issue dozens of DIY Heathkits for amplifiers, preamplifiers, loudspeakers, and just about everything electronic.

Ampex, a manufacturer of high-quality electric motors, produces its first tape recorder, the Model 200 based on the German Magnetophon. The project is bankrolled by Bing Crosby, who uses the 200 to tape his radio broadcasts.

Audio Engineering magazine hits the stands. It later became less professionally oriented and more consumer oriented as *Audio* magazine.

1948

The arrival of Columbia's monaural long-play (LP) record in 1948—along with general post-war prosperity—contributes to the rising interest in high-fidelity equipment. Among many other companies, McIntosh Laboratory, Fisher Radio, and H.H. Scott begin to manufacture components.

The transistor age dawns. Electronic engineers are often frustrated by the singularity of the tube—electron flow is always from negative to positive. They want a device that doesn't require heat for its operation, and they want reversible current flow, which will enable symmetrical circuits and allow direct coupling without capacitors. Although few realize it at the time, the solid-state solution is described in 1948 by John Bardeen and Walter Brattain of Bell Laboratories. From November 17, 1947 to December 23, 1947, Bardeen and Brattain perform experiments and observe that when two gold-point contacts are applied to a crystal of germanium, a signal is produced with the output power greater than the input. The germanium point-contact transistor is a fragile device, prone to oscillation, yet it amplifies and does not require heater power.

The 12AU7 and 12AX7 tubes debut.

Leak introduces its TL/12 Point One amplifier, which, like the Type 15, is also rated at 0.1% THD but offers improved performance.

Harry Olson at the RCA Acoustics Lab directs listening tests into the subjective preference for high-frequency response. The tests indicate that listeners will only tolerate wideband response if the high frequencies are free of odd-order distortion products.

1949

Most electronic equipment prior to 1945 has little or no feedback. In 1949 a novel amplifier design is described by Frank McIntosh and Gordon Gow of McIntosh Laboratory, the Unity Coupled circuit, first used commercially in McIntosh's 50W-1 (and still used in current products). McIntosh and Gow create a new, high-power (50W) amplifier with a guarantee of less than 1% distortion at full power over the entire audio range between 20Hz and 20kHz, and less than 0.25% distortion at mid frequencies. This performance is achieved via a patented system of local feedback loops in the output stage, bifilar transformer windings, and load current supplied from both plate and cathode. The 50W-1 costs nearly $300 with amplifier and power supply on separate chassis and sets a new standard for high-fidelity music reproduction. No other Golden Era amplifier can match it for specifications.

1950

The EL34 pentode is introduced by Philips, Mullard, and Telefunken. It becomes the preferential favorite on the Continent as opposed to the beam tetrodes.

The 15W Quad 1 mono tube amp is introduced.

1951

An "ultralinear" amplifier circuit is proposed and later patented by David Hafler and Herbert Keroes. In 1950, Hafler and Keroes start a Philadelphia-based company called Acrosound in order to build and sell audio-quality output transformers, primarily for home electronics hobbyists. The two men refine and develop a transformer circuit pioneered by British audio electronics engineer Alan Blumlein, using taps from the output transformer to feed signal back into the output-stage screen-grid circuitry. The Acrosound transformer circuit both simplifies and improves existing amplifier designs and is subsequently licensed to the vast majority of Golden Era manufacturers, including Marantz, Harman Kardon, Fisher, Scott, Eico, Heath, Altec-Lansing, Leak, and many others.

Just three years after the original announcement of the transistor in 1948, William Shockley's work on the theoretical aspects of p-n junctions results in the development of the germanium junction transistor, also at Bell Labs. (The term transistor is coined by John R. Pierce as a portmanteau of the term "transfer resistor.") The first consumer application of transistors is in hearing-aid amplifiers, which up to the early 1950s usually contain three subminiature vacuum tubes as amplifiers. In 1954 Regency and Sony market the first transistorized radios. By 1957 the Radio Shack catalog lists DeWald, Hallicrafters, Regency, and "Famous Make" transistor radios at about three times the price of AC/DC tube radios.

1952

Saul Marantz's first product, the $143.50 Audio Consolette, is marketed by the Harvey Radio Company in New York. *Audio* magazine writes, "It merits respect not only for its fine performance...but in itself as a fine example of good engineering and construction." Its design includes two separate high-gain phono preamp input circuits and 36 possible eq curves for the phono section.

1953

Sherwood Electronics Laboratories is founded in Chicago.

The Quad II power amp debuts.

Wireless Engineer publishes R.O. Rowlands' landmark paper "Harmonic Distortion and Negative Feedback" in its June issue. In his paper Rowlands explains mathematically that negative feedback is essentially blameless in the absence of nonlinearity. Rowlands shows that high-order distortion products (Bode's "distortion of distortion") do not arise as a result of feedback for the case of a linear amplifier.

1954

The first working silicon transistor is developed at Bell Labs by Morris Tanenbaum. The first commercial silicon transistors are produced by Texas Instruments in this same year.

The first commercial two-track stereo tapes are released.

The Tung-Sol 6550 beam power tetrode is introduced.

To promote its new 9-pin EZ80, EF86, and EL84 tubes, the Anglo-Dutch Mullard Company develops a very popular mono amplifier circuit, the Mullard 5-10.

H.H. Scott introduces the first commercially successful wideband FM-only tuner, the original 310(A) Broadcast Monitor, which plays a major role in the popular acceptance of FM radio. Scott is also first to market with a stereo MPX adaptor for its tuners, in 1961.

1955

It is not until after WWII that serious efforts are made to standardize recording characteristics within the industry. Before this time, electrical recording technology is considered proprietary, all the way back to the 1925 Western Electric-licensed method first used by Columbia and Victor. As a result, electronics manufacturers produce preamps with adjustable turnover and roll-off frequencies so that users can obtain a flat response from all available records. Among the more sophisticated of these early preamps are those produced by Marantz, McIntosh, and Quad.

McIntosh introduces its C8 Record Compensator. It competes with the Marantz Model 1 Audio Consolette.

After parting ways with Herbert Keroes, David Hafler meets an audio engineer named Ed Laurent, who has designed a novel single-tube driver circuit for a power amplifier. In 1955, the two men found the Dyna Company (later Dynaco) with the intention of not only producing transformers, but also high-quality audio circuitry. Dynaco's first product is the Mk. II 50-watt power amplifier. Available as a kit or pre-assembled unit, the Mk. II is sold for several years until its replacement in 1956 by the Mk. III amplifier, which produces 60 watts.

Richard L. Bright and Richard O. Decker of Westinghouse Electric Corporation file for a patent on a "transistor amplifier for alternating current"—the Class D switching amplifier.

1956

Marantz introduces the Model 2 amplifier, designed by Sidney Smith.

1957

Sidney Frey of Audio Fidelity introduces a mass-produced demonstration disc to encourage development of stereo cartridges.

Max Mathews of Bell Labs develops a process to digitally record sound via computer. He calls his computer program "MUSIC." It is the first computer program for generating digital audio waveforms through direct synthesis.

MOV's KT88 "kinkless tetrode" is introduced to compete with the Tung-Sol 6550. Like the 6550, the KT88 is a beam power tetrode with greater output than the KT66 of 1937.

1958

Marantz introduces the Model 7 preamplifier, which dominates the high-fidelity industry. Over its life, more than 130,000 units are sold and it is honored as the premier example of preamplifier design for many years. The Model 7 uses all-passive tone controls that can be bypassed.

1959

In 1959 Jack Kilby of Texas Instruments describes a solid-state circuit in which all elements (transistors, diodes, resistors, and capacitors) are made by standard semiconductor processes. This first integrated circuit becomes the forerunner of all integrated circuits.

Dynaco introduces its classic ST-70 stereo amplifier, using four EL34 output tubes, one GZ34/5AR4 rectifier tube, two 7199 input (driver) tubes, two output transformers, one power transformer, and a pre-assembled printed circuit board (PCB) containing the driver circuit. It produces 35Wpc.

Harman Kardon markets the Citation II, the first ultra-wideband stereophonic tube amplifier, priced at $229.95. Designed by Stewart Hegeman, it features 60Wpc with a frequency response of 18Hz–60kHz at 20W output. The wide bandwidth allows negative feedback to be more effective at the frequency extremes, because with greater bandwidth comes reduced phase shift (phase shift is the natural accompaniment to roll-off in a filter network). The company promotes its philosophy of designing high-fidelity sound using amplifiers that provide widest-possible audio bandwidth.

The Quad 22 preamp is released. Its variable eq features settings for no fewer than 68 different record labels.

1960

Marantz introduces the Model 9 monaural power amplifier. The 70W Model 9 uses four EL34s per channel instead of the usual pair of 6550s most often seen in high-powered amps of the day. Saul Marantz clearly prefers the EL34 pentode to its beam tube variants (KT66/6L6, KT77, KT88/6550). A modified version of the Model 9 (the 9120) is used by NASA to drive tracking antennas.

The first MOS (metal-oxide semiconductor) transistor is built by John Atalla and Dawon Kahng at Bell Labs.

1961

The first transistor high-fidelity amplifiers are produced in 1961 by Transistronics, the model TEC S 15. A matching tuner, model TEC 15 MPx, is also offered. Almost every U.S. audio company quickly follows suit. Making use of notoriously unreliable "quasi-complementary" output schemes (matched complementary output transistors are not then available) and demonstrating a poor understanding of the transistor's safe operating area, these first-generation solid-state designs sound aggressive and harsh, are loaded with distortions, and fail regularly and catastrophically. At the same time, U.S. manufacturers are facing a tidal wave of more reliable, budget-priced, well-reviewed (in the mainstream audio press, which is supported by the advertising of many of these same well-heeled firms) Japanese imports from companies like Pioneer, Kenwood, and Sansui. Return rates become so bad and Japanese competition so fierce that Scott, Fisher, Sherwood, and many other well-known American brands go out of business in the Sixties, while the Marantz name is sold to the Tushinsky brothers (who own the U.S. distribution rights for Sony).

McIntosh introduces the MC275 tube power amplifier. It is both very heavy and very striking, and becomes the most famous and desirable of the McIntosh tube amps.

1962

Marantz launches its Model 8B stereo power amp (its first stereo amp).

The first transistorized record-playing system, the KLH Model 11, is introduced, using 12 germanium transistors. Packaged in a three-piece suitcase (at a retail price of under $200) and soon emulated by others, this model becomes the successful forerunner of today's compact music systems.

1963

McIntosh introduces the C22 preamplifier. This is to be its final statement in tube preamplification. In topology, it is a precursor of the early Audio Research preamps, such as the SP-2 and SP-3. The C22 uses two 12AX7 gain stages in cascade, buffered by a 12AX7 cathode follower stage. This is the standard gain block of the day, although some—like Dynaco in its PAS preamps—eliminate the cathode follower for reasons of economy.

1964

The Marantz 10B tuner is introduced. One of the most ambitious tuner designs in audio history, the 10B quickly gains the admiration of the most critical audiophiles. Each Model 10B is meticulously aligned in an oven at the actual operating temperature, which results in more accurate performance. Among its many innovations is a CRT screen for signal tuning and displaying multipath and stereo test patterns. This feature, along with the fastidious build-quality and compelling cosmetic design, will earn the 10B its well-deserved status as the Rolls Royce of tube tuners.

Heath

BY ROGER SKOFF

When I was a kid, there were no computer games and not even any home computers to play them on. Because there were no cellphones, either, we couldn't remain in constant contact just by texting or tweeting, and our games were all real—you know, baseball, football, basketball, the kind where you actually had to get together and play them in person if you wanted to play them at all. We had hobbies, too, and, like our games, even those involved actually getting together from time to time to enjoy them.

Hi-fi was the hobby that our little local group of Kid Audiophiles in Van Nuys, California, had gotten into and, just as adult Hi-Fi Crazies do today, we would get together and listen for hours to each other's "systems" (such as they were) and dream and babble and try to impress each other with our knowledge of the memorized "specs" of all the latest equipment.

We mostly talked about specs, because as kids (my pals and I were probably about fourteen at the time) we had all the enthusiasm and the growing knowledge base necessary to put together a great system, but precious little of the necessary money. Memorizing the specs and features of the equipment we lusted after was something we could do cheaply or for free. Other than hunting down used stuff (which we all did whenever we could, and whenever we had the money to buy it), our very best opportunity to improve our systems was in the form of do-it-yourself kits that we either bought or planned to buy, once we could afford them.

Kits were big in those days, and many of the big radio-parts houses—Allied Radio, Radio Shack, Olson Radio, Lafayette Radio, and others—offered their own "house" lines. So did other companies that had grown up mostly supplying test equipment and other gear for radio manufacturers, repair shops, and amateur ("ham") radio operators. Of these, the two most popular with our little group were Heath, whose "Heathkit" line was the clear winner, followed, not all that closely, by EICO (the Electronic Instrument COmpany) and then, at some further distance, by all the rest.

When we first started buying them, Heathkits were the product of the Heath Company of Benton Harbor, Michigan, and we kids loved them because not only were they affordable (my first Heathkit was a Model FM-3A tuner that cost about twenty bucks) and of good quality and generally good performance, but Heath also had a policy of "we won't let you fail," which meant that even somebody who wasn't quite sure that he was supposed to use the hot end of the soldering iron could still be certain that, between the genuinely complete instruction manuals and the available real, live factory help on the telephone, the kit he built would work as well as any other (including the already-factory-assembled units you could buy if, unlike any of us, you were rich or lazy).

Although the Heath Company made its name with kits, and eventually offered most of what was necessary to put together a fairly decent hi-fi system, neither kits nor hi-fi's were the reason for its founding. That occurred back in 1912, and the initial product was…airplanes!

What was to become The Heath Company started in Chicago when Edward Bayard Heath bought the Bates Aircraft Company, changed its name to the E.B. Heath Aerial Vehicle Company, and set out to manufacture small planes. It wasn't until more than a dozen years later, in 1926, that the company first got involved in producing and selling kits, with the Heath "Parasol"—one of a number of do-it-yourself light aircraft available as kits or plans.

With the death of its founder in 1931, the company eventually went bankrupt and was, in 1935, purchased by Howard Anthony and moved to Niles, Michigan, where it concentrated not on building light planes, but on providing accessories for them.

The idea of selling kits still held on, however, and taking advantage of the great leap in technology brought on by World War II, the company became part of the postwar boom in electronics by buying up large quantities of war-surplus parts, developing circuits and housings for their use, and packaging them as do-it-yourself kits, the first of which was a good-quality, fairly full-featured oscilloscope that came out in 1947 for the then very appealing price of just fifty dollars.

By 1956 or thereabouts, when my pals and I got involved, the company had grown considerably, and been acquired by Daystrom, Inc. of Benton Harbor, Michigan. Oscilloscopes—whether that same model or some updated version—were still among Heath's top products, along with a whole line of other electronic test and service equipment. The company had also expanded into and developed growing strength in hi-fi and "ham" radio (another thing that even some of our own group was also actively interested in), and would eventually offer build-it-yourself television sets, for those who either, like us kids, needed to save a buck or who simply wanted the fun and the sense of accomplishment—not to mention the bragging rights—that building it yourself could bring.

And, with all that, how was my FM-3A tuner—that first Heathkit I ever bought? For one thing, it worked just as promised, and I did love to tell people that I had built it. Other than that? I really don't know. For one thing, it was mono—all that was available from anyone at the time. For another, it was subject to thermal "drift"—going off station as it warmed up. But that also was customary for the period. Overall, I'd have to say that it was exactly what the company's products were reputed to be: good quality, utterly reliable, and offering decent but not remarkable performance for a very fair price.

Heath continued building kits across a broad range of categories until 1992, when it discontinued its kit lines—but not its service and support for them—and concentrated on developing educational products. As late as 2013, an attempt was made at reintroducing kit production, but whether that will be successful remains to be seen.

The Heath AA-111 stereo amplifier produced 28Wpc.

David Hafler

Dynaco and the Hafler Company

BY PAUL SEYDOR

David Hafler, founder of Acrosound, Dynaco, and the Hafler Company—one of the seminal figures of both the hi-fi and the high-end eras.

By the time David Hafler died, in 2003 at the age of 84, he owned three homes, one in southeastern Pennsylvania, another in Boca Raton, Florida, and a third in London, with music systems in each of them. According to his daughter Joan Cole, he rarely watched television. These facts tell us at least two significant things about the man who distinguished himself as one of the foremost pioneers of high-fidelity reproduction of music in the home. First, he was very successful in his vocation of audio designer and manufacturer; second, his highest priority was music. This latter was a priority he shared with all the early pioneers of audio such as Edgar Villchur, Peter Walker, and Avery Fisher. Another is what might be called an egalitarian philosophy regarding the dissemination and availability of culture, specifically music, to what Emerson called the "multitudes" (a term far preferable to Marx's "masses"—the latter is an undifferentiated lump, the former a collection of individuals). The dream of those pioneers was to bring the enjoyment of music to anyone willing to expend the effort and set aside the money for a quality system, which they tried to make as affordable as possible.

Hafler was born and grew up in Philadelphia, Pennsylvania, and majored in mathematics at the University of Pennsylvania, from which he graduated in 1940. When Pearl Harbor was attacked he joined the Coast Guard—but not before marrying his high-school girlfriend Gertrude Schwinger—and became a communications specialist, which marked the beginning of a lifelong pursuit of accurate sound reproduction. In 1950, he and Herb Keroes founded Acrosound, which designed and manufactured output transformers for tube amplifiers. Hafler drew upon Alan Blumlein's "ultralinear" circuit, which improved linearity by tying a tap on the transformer's primary winding to a secondary grid. But Hafler was itching to move beyond transformers into full-fledged amplifiers. He and Keroes parted company in 1954 over disagreements about marketing and other aspects of Acrosound.

DYNACO

Hafler teamed with another friend, Ed Laurent, who had already designed a tube amplifier circuit, and together they founded the Dyna Company, which they later renamed Dynaco. It was Hafler's dream not only to sell amplifiers and other electronic components but also to offer them in a kit option. In those days most consumers interested in home audio were real do-it-yourselfers, who pretty much rolled their own from circuit diagrams to parts, even to seeking out metal workers for the chassis. "I saw that there was a hole in the market," Hafler recalled. "I thought there was no reason why there can't be a kit of parts that would make it easy for somebody to assemble an amplifier and save some money over a factory-assembled job."

But the Dynaco kits—dubbed Dynakits—came with a difference. Those from other manufacturers required home assembly of the circuit boards and special test equipment to ensure the finished products met specs. Hafler thought it a much better idea to offer the circuit boards already assembled and tested, so that what was left for the consumer was merely some soldering and assembling of the constituent parts. The first two products were mono amplifiers, the Mk II and Mk III (the Mk I was a prototype never marketed), and both used Hafler's own variation of the ultralinear circuit. Next came a preamplifier, the PAM-1.

By the late Fifties, stereo was already a solid commercial reality, which led to what unquestionably became both Dynaco's and Hafler's signature product: the Stereo 70 tube amplifier. (Laurent and Bob Tucker, another company employee, both had a hand in the design.) The 70 offered 35Wpc, was reasonably priced even assembled—let alone as a kit—and boasted such high performance that it soon earned a reputation as the "poor man's McIntosh." By the time production effectively ended in the latter half of the Seventies, Dynaco had sold 350,000 units, making it the highest-selling tube amplifier in history. Its basic design was so good that Audio Research Corporation sold a kit for

improving it, and several other modifications were marketed by independent designers; for instance, Frank Van Alstine will still take any working Stereo 70 and upgrade it to his Ultimate 70, for which he invites comparison to any tube amp currently available regardless of cost. A companion stereo preamplifier, the PAS 2, was introduced to form the nucleus of an exceptionally high-quality audio system at a moderate price. Throughout much of this period, Dynaco and Acoustic Research often exhibited their products together at trade shows. There were probably more Dynaco/AR systems in use in American homes than any other combination during the late Fifties through the mid-Sixties.

Hafler wasn't about to be left behind in the move to solid-state. In response, he offered the Stereo 120 power amp, with 60Wpc. Introduced in 1966, this was one of the earliest transistor power amplifiers to offer high power—60 watts being high power back then. Though issues of reliability dogged it throughout its entire ten-year run, the 120 could claim excellent measured and audio performance. A companion preamplifier, the PAT-4, another signature product, was offered the following year; like some other preamps, it had the usual bass and treble controls and a "blend" function to counteract the excessive stereo separation of some early two-channel recordings. Dynaco also brought out tuners, including the popular FM-3, and integrated amplifiers, like the SCA-80, a very reliable control amplifier that was easy to build, inexpensive, and excellent sounding.

One of the ways Hafler kept costs down was the rather utilitarian styling of his products. Dynaco components had a house look that was based on function and utility, not glamour and glitz. The amplifiers had wire cages covering the innards, lending a vaguely industrial look; the control units and tuners had plain, silver-tinted faceplates with matching knobs and contrasting black rocker switches—everything looking pretty much off-the-shelf and unobtrusive.

In 1969, Hafler sold Dynaco to Tyco, Inc., but he stayed on as a consultant for a few more years. Meanwhile, Dynaco continued to develop new products, including an extremely highly rated speaker system, the A25, which, at $80 each, eventually sold over a half a million units. During the Seventies, in response to the initial interest in four-channel reproduction, Dynaco came out with Dynaquad in the form of its QD-1 Quadaptor, a novel way of extracting out-of-phase information from a normal stereo signal and feeding it to rear-channel speakers without the need for an active decoder and additional amplification. The effects were unpredictable from one recording to the next, but at its best it generated a reasonable simulacrum of ambient surround that was often more convincing than the SQ and QS systems introduced in that same decade.

But traditional electronics remained Dynaco's mainstay. Throughout the early Seventies a new line of improved preamplifiers (the PAT-5), tuners (the FM-5), and high-powered amplifiers was introduced, beginning with the Stereo-400, which was very well reviewed in *The Absolute Sound*, among other places. Several designers came and went during this period, including James Bongiorno, and Laurent himself even introduced a new tube amplifier, the monoblock Mk VI. However, with Hafler gone, Dynaco couldn't seem to hang onto a real identity as the years progressed, and the company was eventually sold to ESS in 1979, then to the Pan Orient Corporation in the Nineties.

THE HAFLER COMPANY

After a stint with Ortofon, David Hafler started the Hafler Company in 1977 where he essentially repeated the Dynaco formula: moderately priced, plainly styled amps and preamps, available in kit or wired form, of disproportionately high performance. Unquestionably the signature product here was the DH-200 amplifier, which was the first to use MOSFETs (metal-oxide-semiconductor field-effect transistors) in the output stage. At 100Wpc, it was easy to build from a kit—and almost certainly offered a great many audiophiles their first taste of a really powerful amplifier that also sounded superb. Among its other characteristics, the DH-200 exhibited a smoothness rarely associated with solid-state electronics apart from Quad's.

Although Hafler's products were designed for the home market, their performance and reliability brought them much use in the professional sector. Another signature product was the DH-101 preamplifier, followed by a few other preamps.

Hafler's most impressive single amplifier may have been the XL-280 (140Wpc), an amp that, as my colleague Robert E. Greene pointed out in *The Absolute Sound*, started the controversy over what Hafler termed the "Straight Wire Differential Test" or SWDT. He developed a network whereby the output of the amplifier driving a speaker load could be subtracted, after being suitably attenuated, from the input signal. The differential signal in a perfect amplifier would be zero; in the XL-280 it was as low as -70dB down from the signal itself, and the character of the error

The Dynaco Stereo 70, the best-selling tube amplifier of all time.

signal was musical, as opposed to the grit, grain, and hash that many listeners expected from transistors of the era. The XL-280 came with a built-in circuit whereby the consumer could adjust for the lowest possible differential between input and (attenuated) output with the speaker system the amp would be driving. Hafler's claims that this test could establish whether an amplifier was accurate was met with skepticism in some quarters of the high-end journalistic community, but the amp itself is a genuine classic, prized by its owners and very hard to find on the secondhand market. Hafler himself wrote a long and detailed explanation of the test and its validity. This rigorously scientific, laboratory- and measurements-oriented approach was something he shared with all the other early pioneers of audio design such as Edgar Villchur, Peter Walker, Paul Klipsch, Herman Scott, and the designers at McIntosh.

Like Hafler's Dynaco products, the electronics designed under his own name readily lend themselves to after-market modifications and upgrades by third-party designers and audiophiles with a taste for experimenting. All these products are still in high demand among collectors, and it is a testament to the expertise of their design and execution that, like the classic Dynacos, the Haflers still acquit themselves very well among contemporary designs. In 1987, Hafler sold his company to the Rockford Corporation, today owned by Radial Engineering, Ltd., which is planning to relaunch some of the classic Hafler amplifiers. In 1995, Hafler left consumer audio to design electronics for the professional market.

LEGACY

According to his daughter Joan, Hafler "loved music." But he never developed enough skill to play professionally. So instead he manufactured the best sound equipment possible. He also loved to play chess, but he wasn't a world-class player. So he became "a world-class collector." He acquired a collection of 240 classic chess sets from around the globe that experts widely regarded as one of the finest in the world. As for audio, in 1984, he was named to the Audio Hall of Fame, and in the Nineties, the Dynaco Mk II 50-watt amplifier was displayed in the Smithsonian's Museum of American History in Washington, D.C. Although Hafler always designed his products to a price point, performance remained uncompromised within the given specifications and the technology of the times. "It was a case of price-no-object-in-reverse," observed J. Gordon Holt: "a modest outlay brought you sound that made McIntosh owners feel as if they had been had!" Among the early pioneers of audio, only Edgar Villchur was of equal importance to David Hafler in making home high-fidelity a commercial reality, but Hafler made it a lifelong career and never stopped designing products that met his twin goals of high accuracy and exceptional affordability.

David Hafler in His Own Words

On the design of the PAM-1 preamp: "Just about the time we were ordering parts, I noticed a peculiar kind of noise coming from it when it was turned all the way up. The prototype didn't have the noise problem. I tried everything that I could think of for weeks…I even had Stewart Hegeman come in from New York…He took a look at and couldn't find the answer.

"I finally resolved the thing by taking the preamp apart, piece by piece, and interchanging parts between my breadboard unit and the pre-production unit. I found that the low-noise resistors were noisier than anybody could have anticipated. They were just no good. It took me all that time to find it because they were consistent."

On early marketing: "I first met Edgar Villchur in 1953 or 1954…The AR speaker [the AR-3] required a high-powered amplifier because it was very inefficient. We brought out an amplifier that did an excellent job into the AR speakers…This turned out to be a great marketing arrangement because we could go to hi-fi shows and share the expenses. AR sold speakers and we sold our amplifiers with no conflict of interest, but complementary activity…AR rented a space in Grand Central Station in New York, for product demonstration purposes. Anybody who walked through the station and had time to kill between trains could go in and hear some AR and Dynaco working together. We paid AR for half of that, of course. Even after AR came out with its own amplifier, we still had a close relationship."

On designing the first kits: "Bob Tucker was very good at thinking of what problems a customer might have and trying to eliminate them. Anything that we were going to put out, he field-tested very thoroughly. He assembled them himself. We also used people who were not skilled to assemble the kits under Bob's watchful eye. He could see firsthand where they ran into problems and he could make adjustments. The manual was an important part of the kit, too, of course."

On the straight-wire differential test: "Should an amplifier be pleasant sounding, or should it be accurate even if accuracy is not as pleasant? The SWDT reveals accuracy or the lack of it. It is the only way to assess accuracy directly and objectively with the amplifier operating under normal signal and load conditions—and it does this in real time, with a dynamic signal source. It encompasses all forms of distortion. It requires no special instrumentation or skill. If the residual 'null' is inaudible, the conclusion that the amplifier is accurate is unequivocal. Can anyone suggest a more meaningful or practical test of amplifier accuracy?"

Thoughts on audio today [circa 1999]: "You are not going to like my feelings, I'm afraid. There is a big rip-off going on. Companies are selling extra-high-priced equipment that has no benefit except a high profit to the company that sells it. I don't think that many of these fads that come along are true advances."

Sources: The first four quotations are excerpted from an interview conducted by Charles Kittleson in Valley Tube Valley *in 1999 (http://www.hafler.com/pdf/interview-with-hafler-pt1.pdf). Hafler's remarks on the differential test are from his manufacturer's comment to a review in* Stereophile *in 1987 (http://www.stereophile.com/content/manufacturers-comment-0). A more detailed history of Dynaco is in Gregg Dunn's "Dynaco Company History" (http://home.indy.net/~greggdunn/dynaco/history.html).*

The Five Most Significant Tube Amplifiers

BY BOB CARVER

Clockwise from top left: Harman Kardon Citation II, Marantz 8B, Williamson, Dynaco Mk III, and McIntosh 275 amplifiers.

Probably three of the most beloved and admired amplifiers from the Golden Age of Hi-Fi are the McIntosh MC275, the Marantz Model 9, and the Harman Kardon Citation II. If we add the venerable Dyna Mk III and Williamson to this line-up, we have covered all the existing examples of circuit designs that were in use back then. Believe it or not, there were only four circuit designs, plus the one-off McIntosh.

Let's take a look at each in turn after we look at the things they have in common. First, they all appeared on the audio horizon at about the same time: the late Fifties and early Sixties. All delivered between 60 and 75 watts per channel, and all used either 6550, KT88, EL34, or 6CA7 output tubes. (The KT88 is the British version of the 6550, and the 6CA7 is the American version of the EL34.) Now comes the best part: Each of these beautiful amplifiers represented, in its own way, one of the four circuit topologies that evolved and came to represent the state of the vacuum-tube art. And remarkably, these topologies were destined to remain unchanged for the next five decades. That's because each in turn represented the very best, most advanced and efficient way of delivering superb sound with high power, low distortion, and relatively low cost. The evolution of these circuits took only a few years, but the results show that when technological development is good, products will stand the test of time.

Top: McIntosh MC275.

Bottom: Marantz 8B.

MCINTOSH MC275 STEREO AMPLIFIER

I begin with the McIntosh MC275, the design that ushered in the explosive growth of hi-fi. For context, we have to go back a few years before the MC275. At the time, designers were working to develop high-power amps in order to deliver more realism, greater fidelity, and that wonderful sense of being in the presence of greatness at a live concert. The problem was that in order to get more power, Class AB amplifiers were needed, and yet nobody knew how to build a Class AB push-pull output stage that was free of "notch" distortion—an insidious, horrible-sounding, rapid discontinuity in the musical waveform at the moment when it crosses the "zero" axis from positive to negative. The only way a smooth transition could be made was to use a Class A design, which by its nature was free of any such discontinuities.

Many brilliant designers around the world devoted themselves to solving the problem of notch distortion when, one day, a young engineering genius by the name of Gordon Gow found the solution. By doing so, he was able to lift distortion-free power output from about 7 watts to 75 watts. And the high-fidelity industry took off.

The design was so successful that he and his partner Frank McIntosh started an amplifier company that has lasted to this day. Gow's solution was ingenious because, you see, "notch distortion" is the result of the ineluctable fact that when current in an inductor is interrupted, a large voltage spike occurs. In Class AB, this takes place when one tube switches off and the other switches on. Gordon Gow figured that if he wound the coils of his output transformer so that it did not exhibit any inductance, then the spike, and hence the crossover notch distortion, would go away. He did this by winding the coils of wire inside his output transformer so closely together they behaved as one long wire in which the current was not interrupted as the handoff from one tube to the next occurred. An engineer would call this "bifilar" winding. Eliminating crossover distortion was easy by comparison; all a designer had to do was make certain that one tube was turned off as smoothly as possible, while leaving the other tube on for a bit during the turnoff. By designing the bifilar-wound output transformer and by coordinating the turn-on and turn-off sequence, both notch distortion and crossover distortion were completely eliminated.

Other designers followed Gow's example, developing their own circuits, and the high-fidelity industry became a bright field of creativity in vacuum-tube amplifier design.

The MC275's circuitry is a special mixture of the 520 topology (see Marantz Model 9 below), combined with Gordon Gow's very unusual and unique output stage—one that only McIntosh has ever used. It comprised a 12AX7 triode driving the classic 520 long-tail inverter designed by the Mullard company in England. However, instead of driving the output tube grids directly, as in most other 520 circuits, the McIntosh circuit drives another pair of tubes formatted as an additional differential pair, and they in turn drive cathode followers that are placed between the differential amp and the output tube grids.

Now comes the magic part: There are no adjustments on this output stage! Gordon Gow's transformer design was so remarkable that the normal bias and balance adjustments could be dispensed with. The complex winding geometry allowed full power to be obtained even at the frequency extremes.

MARANTZ MODEL 9 MONOBLOCK AND MODEL 8B STEREO AMPLIFIERS

The Marantz Model 9 was an incredible looking and sounding amplifier designed by two exceptionally talented men, Saul Marantz and Sid Smith. Saul did the industrial (cosmetic) design, and Sid did the circuit. This unit represents one of the four topologies that exist in our amplifier universe, and it goes by the name of the Mullard circuit, or more affectionately, the 520 circuit.

The original 520 circuit had five tubes and delivered 20 watts. The 520 is characterized by a single input triode or pentode tube that's direct coupled to a differential amplifier pair comprising a dual triode. The upper of the pair drives the control grid of the top output tube, and the lower of the pair drives the bottom output tube. This circuit is used by more amplifier designers than any other.

The Model 9 is arguably the finest example of the 520 circuit. Using a triode in front of and driving a differential pair, followed by a cathode follower, serves to drive the output grids of a double pair of high-power output tubes (four output tubes in all). This circuit delivers almost 100 watts, and Marantz conservatively rated it at 70 watts for an important reason. As it turns out, it's extremely difficult to deliver full power at all frequencies across the full audio band from 20Hz to 20kHz, and the most conservative way around this problem is to build one's amplifier to be sufficiently powerful so that even if the power at the frequency extreme falls a dB or more, it will still be within the unit's rated output. This was easy to do, as the Model 9 was a mono amplifier as opposed to a stereo amp; thus, the extreme stress of driving both channels at full power at 20kHz was avoided.

This amplifier had so many innovations secreted in its circuits I hardly know where to start. The first is that it used four smaller output tubes instead of just two large ones. This yielded an output stage balance that was, on average, twice as good as could be obtained with only two tubes. An important, original, and ingenious thing Sid Smith did to prevent "gulp" distortion (something that occurs when power-supply voltages swing up and down to the time of the music) was to design a circuit that used as its input signal a portion of the "swing" in the power supply to cancel "gulp" distortion out. I can imagine the first time a Marantz competitor had the amp on his lab bench and noted that it totally lacked "gulp" distortion: It would have seemed impossible!

Another innovation was the way the Model 9 was "frequency compensated" for stability. All amps are frequency compensated, but they also suffer from

some negative side effects of this compensation, which results in higher distortion and significantly lower power at 20kHz. Sid developed a high-frequency feedback-compensation scheme that did not have any detrimental effect during high-frequency full-power operation. (His feedback invention was so remarkable that I copied it. Luckily for me the circuit was in the public domain, with the patents having run their course years ago.)

Neither of these innovations had ever been seen before. They were truly original, and helped make the Model 9 such a remarkable standout—a dream amp if one had the money. The Model 9 is also so attractively styled that whenever we gaze upon a pair we are struck like a bolt from the blue with the thought: "It just doesn't get any better than this!"

The input stage consists of a 6DJ8 dual triode tube, a tube that is still in current use and is very popular with preamp designers. The output of the 6DJ8 drives a standard Mullard grounded-grid phase inverter comprised of a long-tailed differential pair, and is the second dual triode 6DJ8. The output of this differential amp drives a pair of cathode followers that in turn drive the grids of the output tubes via a set of four coupling capacitors. The capacitors provide for extreme DC stability in the face of changing AC line voltages, or the natural aging of the 6DJ8 inverter. The output transformer is very large, allowing a design path that yields extremely fine, full-power, high-frequency response, and of course low-frequency, too.

The negative feedback is taken from the secondary of the output transformer by use of a separate winding dedicated to supplying the necessary feedback signal voltage. A very unusual feature for the time was a method for changing the output stage from ultralinear operation to straight triode. This feature was also on the 8B, but in a rather clumsy form. It was necessary to unsolder several wires and then attach them back up but in different places. This proved to be such a popular option that Sid Smith installed a switch, allowing straight triode operation simply by throwing it into "triode" mode.

WILLIAMSON AMPLIFIER (AKA, THE HEATHKIT W-6M MONOBLOCK)

One of the very first amplifiers to possess almost all the attributes that we expect from a modern tube amplifier was the original "Williamson." Its circuit was novel when it first appeared in the late 1940s.

The inventor of this topology was a man named D.T.N. Williamson, and he absolutely hit on a great idea that was significantly different from the way circuits were generally arranged at the time. He used what came to be called the cathodyne phase inverter to drive a pair of separate driver tubes whose only job was to deliver high drive voltage to the output tube grids. After he developed that drive circuit, he designed a new kind of output transformer that delivered high power without notch distortion. In order to get the transformer to work correctly, though, he had to use triodes because there was no way to eliminate notch distortion unless this output transformer was driven by a low source impedance, and triodes characteristically have extremely low source impedance. Williamson treated the transformer in a very special way that resulted in zero notch

The Williamson amplifier.

distortion by building it so that there were many windings inside that were segmented, and each segment was brought outside the transformer with separate wires to be hooked up externally (about 26 wires, as I recall).

The Heath Company, of kit fame, used the Williamson circuit exclusively in all its best, most powerful amps. And soon, output transformers were developed that did not require a low source-impedance drive, setting the stage for high-power, zero-notch-distortion Class AB amplifiers. We can think of this design as the start of the modern, low-distortion, low-source-impedance, high-power tube amplifiers that we enjoy today. Though it had only a few watts when it first appeared, as soon as circuit designers absorbed the basic topology, power output went up very quickly, until Heathkit topped it out at 70 watts in its W-6M, close to the standard for high-power amps of the time.

The W-6M was a beautiful amplifier with a soft, sand-colored semi-gloss paint job, and gloss-black transformers (and they were huge)! It had a large front-panel-mounted bias meter, separate bias and balance controls, and a variable damping control. On the upper right was a gold nameplate that proudly said Heathkit. That it only had one fuse anywhere—no power supply fuse, no tube fuses, just a single AC line fuse—was a recipe for disaster in the event of a power tube going bad and shorting out. The short-circuit current would flow through the bias meter unabated, and blow the meter up. Other than that, this amp was beautifully built. It had a pair of big Coke-bottle Tung-Sol 6550s, a Williamson front end that consisted of the ubiquitous 12AU7, a 12AX7, and a 12BH7. Unfortunately, the 12BH7 was direct coupled to the grids of the output tubes, and sure enough, the output stage could be unstable. (Today these amplifiers have a reputation for being problematical regarding bias stability. The problem is easy to fix, though.)

The W-6M had a very advanced power supply that incorporated a topology that has stood the test of time, and is still used extensively today. It utilized a voltage doubler with the relatively new silicon diodes. Only the Marantz, the Citation, and the McIntosh models used these diodes, as far as I know. Ultralinear taps on the screen grids rounded out the circuit. All in all, this amp is well built and competent, and uses the tried-and-true Williamson topology that has been substantially upgraded from the original to deliver 70 watts.

DYNACO MARK III MONOBLOCK AMPLIFIER

The Dyna Mark III monoblock amplifier was destined to become the most ubiquitous, most popular big tube amp of them all. It was an extremely successful design because it was very easy to build, possessed excellent performance, and was probably the most inexpensive big tube amp of all time. I remember a meeting with a McIntosh factory representative in which he wondered out loud, "How did they do it and sell it so cheaply?"

Only David Hafler, Dyna's founder, knew. This amp had lots of good stuff inside: large output transformers that were among the very best, a pair of British-made KT88 output tubes, a cathodyne phase inverter, a chromed chassis, and one of the first printed circuit boards ever, helping to make for foolproof kit-building. I can remember helping a friend of mine build one long ago, and when we finished and plugged it in, and it worked, we were on cloud nine. I think we danced around the room several times. The point is that the Dyna Mark III made for such a feel-good, over-the-top building experience, as well as being such a great amp, it could not help but be a hot sales item. And it delivered 60 watts!

Top: Harman Kardon Citation II.

Bottom: The Dynaco Mk III.

The input stage was one half of a 6AN8 small-signal tube driving a cathodyne phase inverter. The output of the cathodyne drove the grids of the output tubes, and against all odds it worked. This simplest of all topologies was well known and had been used for years, but only for driving small power amps using the many low-power output tubes that were readily available. Ingeniously, Hafler's circuit design was able to drive the grids of the mighty 6550/KT88 output tubes for a full 60 watts of audio power! The plate of the 6AN8 was direct coupled to the cathodyne grid, which was the absolute simplest way to couple the two stages together. The 6550/KT88s were wired to the output transformer in the conventional Ultralinear fashion, and delivered full bandwidth with extremely low distortion. No wonder this was the most successful large 6550/KT88 tube amp ever made, in both dollar volume as well as unit volume.

HARMAN KARDONV CITATION II STEREO AMPLIFIER

This amplifier captured the imagination of a large number of us who love vacuum in a glass bottle. The Citation II is Stu Hegeman's second-best design. (His best work, by his own admission, was his Lafayette 550.) Both amplifiers are truly monumental works. In fact, I will go out on a limb and say that, for sheer brilliance, they are the amplifier designer's equivalent of Beethoven's Ninth Symphony or Puccini's *Tosca*, for this design was absolutely original in concept as well as execution.

All the other designs mentioned here had some sort of evolutionary past before finding their ultimate expression. But the Citation II was completely new. There had been nothing like it before, and there has not been anything like it since. It was an outgrowth of Hegeman's belief that the ultimate amplifier had to have a bandwidth that includes several octaves above and below the normal range of human hearing—that an extreme bandwidth would yield sonic magic. In order to obtain the wide-bandwidth goals he set for himself—and we are talking upward of a megahertz—Hegeman decided to use high-frequency video amplifier tubes, since video signals contain frequencies beyond 4.5MHz. This was a price-no-object design, so Stu chose the widest-band video pentodes possible. Six of them! Six 12BY7 video pentodes were expensive back then. Only the best, most advanced television receivers used them when this amplifier hit the market in 1959.

In order to complement the high-frequency-video drive, the output transformer also had to have a frequency response as wide as possible. The transformer took almost two years to develop; there had never been anything like it. It's a tribute to the Freed Transformer Company, Sidney Harman, and Stu Hegeman that this amazing device came into being. Its frequency response extended beyond 240kHz. No notch distortion, no crossover distortion, just a perfect transfer function.

The input stage comprises a 12BY7 high-frequency video pentode with a frequency response that easily exceeds 6MHz, meaning that 20kHz was just a walk in the park.

Its B+ power is supplied by a separate RC filter that performs three jobs: one, it filters the supply voltage for the input stage; two, it provides extensive separation between the channels; and three, it provides a measure of "gulp distortion" immunity for the whole amplifier. (To remind you: Gulp distortion occurs when the power supply bounces up and down to the time of the music and is inadvertently coupled into the amplifier gain stages. This problem, at the time, was considered unavoidable simply because large energy storage capacitors were not available then. Only Sid Smith of Marantz had figured out a way of making gulp distortion vanish, and I don't think he told anyone how he did it.)

The output of this stage is AC coupled to the driver stage, another 12BY7 into which are fed four different signals. One is the main drive signal from the preceding input stage, another is a feedback signal fed from the primary of the output transformer, a third is a feedback signal from its own plate, forming an anode follower. (Anode followers were Stu's favorite gain stage topology, and one we see used over and over again in his designs. Many of my colleagues firmly believe that cathode followers hurt the sound, and therefore refuse to use them if an anode follower can be used instead. One of my friends went so far as to say their use "ruins" the sound. Strong words, but too many people agree with this sentiment to take chances or to tempt fate; use an anode follower instead!) The fourth signal is fed to its cathode via the "longtail" formed by the differential amp, also a 12BY7 whose screen grids are sourced from a single, large unbypassed screen resistor. This arrangement is pure Hegeman!