The Signal

OFFICIAL MAGAZINE OF THE
COLLINS COLLECTORS ASSOCIATION
Q2 2018 Issue #90

# Not Your Father's Boeing: Then and Now


## Michael Collins In The New Boeing 787 Dreamliner

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Collins Collectors Association

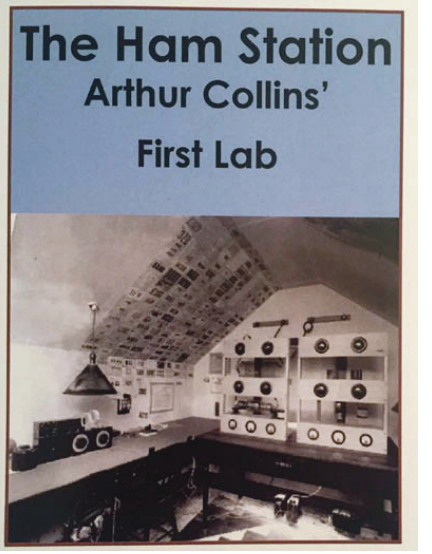
# From the President's Desk…

Welcome to this new expanded issue of the Signal! The CCA is going strong and our membership has reached an all time high. We value each one of you and I appreciate the way all of you have come together to make the CCA the great organization that it is.

Dayton was a great event. It was good to catch up with so many of you and we had a great time at the Collins booth with many guests and friends. Each one of you are a different part of the Collins story. The highlight for me came as I was sitting in the booth and Paul Johnston, W9PJ came up to me and gave me a very special treasure! Back in 1948 Jim Miller, W9NTV (now W4JR) took his Collins 32V-1 transmitter back to the factory in Cedar Rapids because it was not working. Mr. Collins met him and immediately had the radio taken to a lab. While it was being repaired, Mr. Collins gave Jim a tour of the plant and Jim's wife was


treated to a special time with some ladies. At the end of the tour Mr. Collins presented Jim with a winged emblem that had been made into a key chain and placed in a black jewelry box. Jim is 95, a WW2 Vet, and former VOA engineer. Jim and Paul discussed giving it to me because of my work in restoring the Collins Van. I am so thankful!

Our cover of this issue displays the new Boeing 787 Dreamliner which was recently rolled out at the Boeing factory in Seattle for Norwegian Air. The airline honored Mr. Collins in its special series of "Tail Fin Heroes." Michael, the eldest son of Arthur Collins, attended the event to represent the Collins Family and had a special time. Rockwell Collins, Boeing, and Norwegian Air worked together remarkably to accomplish this story. Michael, (along with other members of the AACLA), is is thankful for any opportunity to tell the real story of Mr. Collins and the Collins Radio Company.




I am working with Michael, Loney Duncan, Rod Blocksome, Keith Erickson and others to create a portable replica of the first Collins ham station which we are calling the First Collins Lab. It will tell the Collins story to a new generation of young people and be complete with copies of the QSL cards and replicas of 3 generations of various equipment layouts that Mr. Collins set up in the early days. Loney is writing an exciting article on the Collins Pi network which has it roots in these early days for the Q3 Signal. Please let me know if you would like to support this project!

Loney Duncan was our speaker at the Dayton Banquet and presents an excellent article in this issue. He describes a project he is working on to restore a C-97 aircraft like the one used in the famous SAC flight when Mr. Collins used a set of Gold Dust Twins to convince the military to change from AM to SSB. This is an amazing piece of Collins History and ham radio played an important role. Loney mentions the need for a KWS-1 to outfit this airplane as it was then. If anyone has an extra KWS-1 that you would like to use to make history, please let me know!

The CCA dinner at the Long Branch in Cedar Rapids is coming up soon. It will begin 6PM August 3, 2018, followed by the Cedar Rapids Ham Fest on August 4. We will be gathering as many of the original players in the KWM-380 project along with the Goldwater HF-380, the Serial #1000 KWM-380, the 451S-1,and HF-380A green radio, for a picture. This is our last chance to ever have a gathering of these original people. Our speaker will be Dave Berner. I have visited Dave at his home and have learned so much. Please sign up on the CCA Web site. There will be 380 prizes, fellowship, and tours of the museum! We are expecting over 60 CCA and local people.

Finally, I have been privileged to check in to the 20 Meter Sunday net at 14.263 and have been really impressed. When the band conditions permit, we have a strong net with a lot of great NCO's and check ins. Thank you to James Hollabaugh and his group of 12-14 NCO's who maintain these nets. Torrey Mitchell, N9PY, is very active in the 20 Meter net and recently updated our preamble which is read every time a net begins. I encourage you to join our CCA nets as you have an opportunity. Bring a grand kid with you and get them excited about the hobby. This is how I got into the hobby!

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## The Signal Magazine

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You can renew your membership or join the CCA on our website using the "JOIN US" link.



## From the President Continued...

CCA Net Preamble (May 29, 2018)

This is call sign, phonetic call sign, my name is___, and my location is city, state. I'll be your net control station today along with _____. Welcome to the regular Sunday afternoon edition of the Collins Collectors Association "Collins" net. We meet here every Sunday afternoon at 2000 UTC to exchange information on Collins Radio related topics. We welcome questions and comments on the restoration and operation of Collins Amateur, Military and Commercial gear. "In for the numbers" check-ins are always welcome. You don't have to be running Collins equipment to join us. Anyone with an interest in Collins Radio is welcome to check in.

SSB nets are held:
Tuesdays and Fridays on 3775 KHz, 8:30 – 10:00 PM Central time
Fridays on 3895 KHz at 8 PM Pacific Time;
Sundays on 14.263 MHz at 2000 UTC.

There is an AM net on the first Wednesday of each month on +/- 3880 KHz at 6 - 8 PM in the East, 7 PM in the Central and 8 PM in the Mountain and Pacific time. The net is "on hold" June through September because of heavy static levels.

The purpose of the CCA is to promote the preservation, restoration and use of Collins Amateur Radio equipment, and to preserve the history and lore of Collins Radio. In addition we provide a technical and historical information archive for Collins Radio information. The CCA is licensed by Rockwell Collins to use images, logos, manuals, and printed materials.

For more information about the Collins Collectors Association, its forums, activities, services and how to become a member, please visit our website at: www.collinsradio.org. That's collinsradio, one word, dot O R G. Please help our efforts by joining the Collins Collectors Association.

This 20-meter net will commence with an open check-in section for buy-sell-or swap and will be followed by calls for regional general check-ins starting with call areas 1-4, then areas 8-9, followed by areas 5 and 10, and closing with areas 6 and 7. During low points in the solar cycle, the 6th and 7th call districts will be called following areas 8 and 9. Otherwise, propagation to the west coast may be gone later in the day. Please check in according to the call area where you are located.

DX and mobile check-ins will be accepted as they call, but there will be DX check-in windows after this preamble, after the 5's, after the 7's and at the close of the net.

-Jim Stitzinger, WA3CEX
CCA President

Torrey Mitchell, N9PY

# Tail Fin Hero

By Michael M. Collins, PhD


ABOVE: Michael M. Collins standing in front of the Boeing 787, branded with his father, Arthur Collins' image.

Soon after its founding in 2002 Norwegian Air chose to literally brand its planes with a bold and distinguishing corporate symbol: images of "tail fin heroes", people from many backgrounds but in all cases those who were pioneers, establishing new boundaries in their field. Most are Scandinavians, but many nevertheless familiar to Americans such as the artist Eduard Munch, the explorer Thor Heyerdahl, as well as others including the English entrepreneur Freddie Laker, and now the American electronics inventor and businessman Arthur A. Collins.

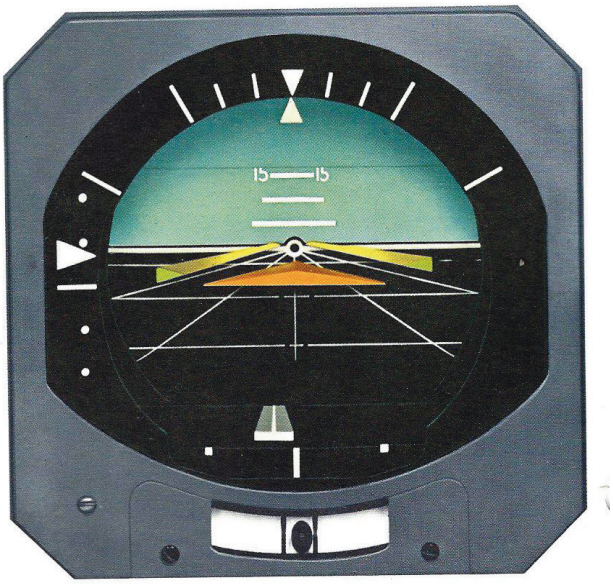
In the summer of 2017 I was contacted by Dave Yoeman of Rockwell Collins, who passed on a request from Norwegian Air asking me, as a representative of the Collins family, for permission to so honor my father Arthur Collins.

They asked for pictures of AAC to be used in direct rendition as well as a basis for artwork for the tail fin image.

Rod Blocksome (retired Rockwell Collins engineer and AACLA board member) and I gathered several images of proper content and resolution.

After submitting these, we all waited patiently for the promised spring of 2018 roll out of the so-adorned new Boeing 787.

In early March Boeing and Norwegian Air asked if I would like to visit during the handover. My wife Pat and I gratefully accepted and flew to Seattle on March 8.




329B-7C Flight Director Indicator (Actual Size) 331A-6A Course Indicator

Corey Mosely, head of the RC field office on site at Boeing, kindly drove us to Boeing on an appropriately rainy morning, where we were graciously treated to breakfast and a brief ceremony.

We then drove to the newly-certified 787 and given a tour around and inside the aircraft. I enclose a shot of Corey explaining the basic functions of the RC glass cockpit (see cover). This was poignant for me since I grew up around airplanes and flew with Dad as pilot in a succession of aircraft. Collins Radio was a pioneer in flight control instrumentation, in addition to communication and navigation gear, and AAC held a 1951 patent for the original horizontal situation/ course deviation indicator. We were building the revolutionary FD-108/9 when I worked for Fred Johnson and Harry Passman in Cedar Rapids in the mid-1960s.


Aviation, Boeing Aircraft, and Arthur Collins have a long, mutual, interwoven history.

We got a tour also of the assembly area for the 787. A huge place; I was reminded of the Vehicle Assembly Bldg. at Cape Canaveral. My first impression was how quiet it was due to the elimination of mass riveting of panels. Most of the plane is carbon fiber based material. Pat and I were so lucky to have been invited. Corey's lasting comment to me was how very seldom he saw failure of the old avionics gear, during the time he was a travelling field rep. (Most problems were wiring, incorrect installation or modification, or worn plugs.)

The Collins family is certainly grateful to have been a part of this event. Our collective thought was that Dad would have been embarrassed at all the fuss!

I would like to thank all those at Boeing Co. who extended their hospitality, and to Corey Mosely (Rockwell Collins) and Atle Straume (Norwegian Air) for sharing their knowledge and enthusiasm.


ABOVE: The Seattle Rockwell Collins crew. From left to right: Phil Bates, Chris Thompsen, Will Cooper, Brian Aiken, Corey Mosely.

# Historic SAC-Collins 1956 SSB Flights

By Loney Duncan, W0GZV

When I joined Collins Radio in March of 1957, I found myself in the middle of an HF Single Sideband revolution. Arthur Collins had previously assembled an intensive task team to study, design, experiment and test circuitry for superior but affordable SSB. Vince DeLong, one of team, had given a talk to my senior class at Kansas University the fall before, and the IRE Proceedings on SSB had a majority of papers from Collins. So, I was hooked. I was interviewed and hired.

Collins had developed the 75A-4 receiver, and the KWS-1 transmitter for SSB amateur sales, but it was very evident that the technology was going far beyond that. When I arrived, the buzz was about two C-97 flights with the Vice Commander of the Strategic Air Command (SAC) and Arthur Collins successfully communicating with large numbers of hams with these two SSB radios as they flew over the north Pacific and Atlantic regions.

The unusual results of these flights finally convinced skeptics at SAC that SSB was substantially superior to AM for aircraft long distance communication, especially over the polar regions. These results would have far reaching influence toward new, complex, HF command and control communications for SAC's aircraft.

It's intriguing to me how it happened in the first place. SAC Vice-Commander, Major General Francis (Butch) Griswold, was an avid ham, K0DWC, and was well acquainted with Arthur Collins and Collins Radio. Both loved sports cars.

SAC was transitioning from B-47s and B-36s to the newly developed B-52 bombers in the middle of a Cold War. Typical USAF radios were the Mil version of the Collins 618S AM 100-watt transceiver, and these were not performing sufficiently for worldwide command and control of these nuclear deterrent bombers.

A superior HF voice mode, higher power, and a new communication system were badly needed.

Arthur had loaned the "Gold Dust Twins" to both Griswold and his boss, General Curtis LeMay, Commander of SAC. He convinced them to install some of these new radios aboard Griswold's command post C-97A and run some significant communication tests with hams, especially from the northern latitudes.

Griswold's C-97A is shown at the Collins Cedar Rapids hanger in Figure 1. This 70-ton aircraft was a military version of Boeing's 377 commercial Stratocruiser, and although the same length as a B-29, was much larger in diameter and had greater height. Further, each of its engines was 3500 HP compared to the B-29's 2200. USAF used these mainly as cargo and refueling tanker planes.

The installation would be simple. Two 75A-4s and a KWS-1 would be powered on the aircraft's 400 Hz mains. Collins knew that transformer losses would be minimal at 400 Hz, and that only the transmitter blower would have to be changed out for that power frequency. These were lab tested as such.

It was attempted to use the aircraft's automatic 180L antenna coupler to match the wire antenna, but the additional power over that of the on-board 618S, damaged the coupler. A higher power manual coupler was quickly designed for the flights and called the 180S-1.

Figures 2 and 3 show the radio position setup. One 75A-4 and the KWS-1 face the operator, and the spotting 75A-4 sets on the KWS-1 power supply on the left side. The antenna coupler shown in Figure 4 was mounted close to the wire antenna penetration of the fuselage. All of these were mounted on vibration isolators.

Figure 1: General Griswold's C-97A

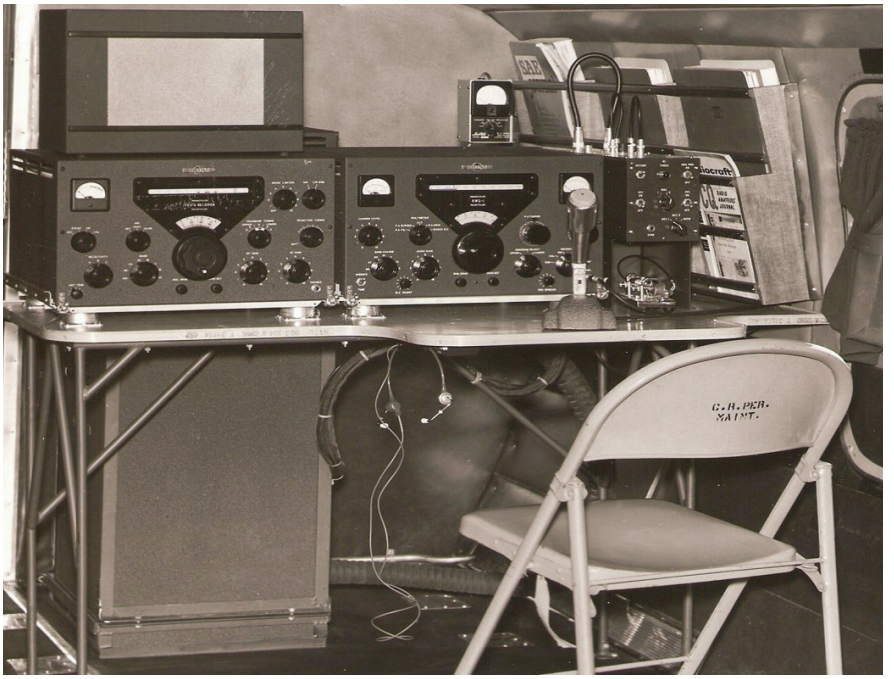


Figure 2: Radio Position, Front

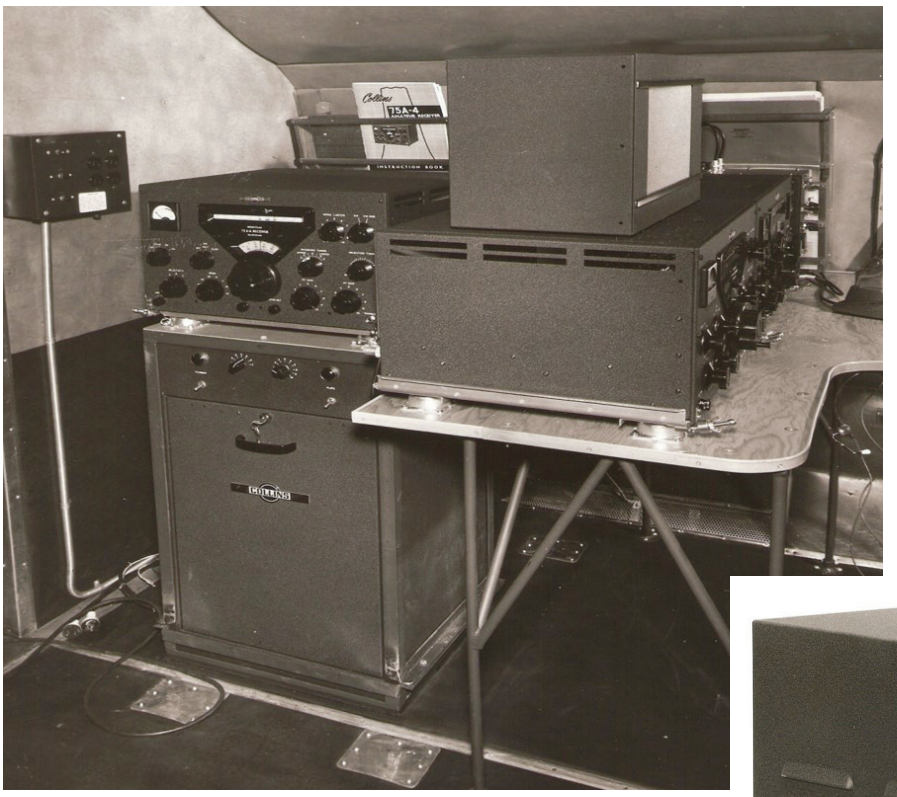


Figure 3: Radio Position, Left Side

Not withstanding the success of the flight, there were still Air Force skeptics about SSB replacing conventional AM, and whether it would provide substantial improvement in the polar regions. So, a second flight was planned over the North Atlantic that would definitely penetrate these regions of concern.

The March 25-April 3 flight was to appear as a routine Griswold inspection tour of SAC bases in the Pacific. The QSL card for the flight, Figure 5, shows Arthur Collins, General Griswold, and Sergeant Wilson, the most active ham at SAC headquarters. W0CXX, of course, was Arthur's famous call. Also, aboard was a crew of eleven and Griswold's staff.

There was considerable preparation for this flight, with key Collins hams set up at the Cedar Rapids, Dallas, Burbank sites, and personnel at SAC headquarters at Offutt AFB, Omaha. This multiple site concept was key to future SAC HF systems, as I will describe later. Propagation studies were produced for the trip.

A map of the flight is shown in Figure 6. From Omaha, the flight would go to Alaska, Tokyo, Okinawa, Guam, Honolulu, San Francisco, and back to Omaha, 71 flight hours total. Over 1000 ham contacts, with 26 countries, including the USSR, were made on the SSB equipment! Comparisons with the on-board AM Collins 618S showed SSB to be far superior, certainly no surprise to the three operators.

Figure 4: 180S-1 Antenna Coupler


Figure 5: Flight 1 QSL Card

This flight of June 29-July 7 added a USAF communications officer from the Rome Airforce Development Center (RADC), and two from SAC. Additionally, Melville Grosvenor and an associate from the National Geographic, and Leo Meyerson of World Radio fame were on board. Figure 7 shows Collins, Grosvenor, and Griswold at the radio position.

The flight left Omaha for Andrews AFB and other eastern US bases, and proceeded to Goose Bay Labrador, Thule Greenland, over the polar region to Alaska, then to California and back to Omaha.

Total flight time was 42 hours, and over 1200 contacts were made, 25 countries. One of these was Arthur's 3-hour QSO from the North Polar region to the Navy KC4USA station at the Antarctica base, pole to pole! Again, there were the key Collins hams at the three Collins locations supporting the flight day and night. And the results really underscored the superiority of SSB over AM in the polar regions.

It is noteworthy that there was an additional radio aboard this flight. It was the Collins prototype 1 kW PEP, 28,000 channels, 2-30 MHz airborne transceiver on contract with RADC, to be known as the ARC-58 that Scott Johnson described in a recent Signal. This radio would go on every B-52, using an automatic antenna coupler located at the base of the vertical stabilizer "tail cap" antenna. The coupler had very challenging temperature and vibration requirements.

Although SAC was on a development path to the ARC-58 for the B-52s and powerful SSB ground stations, through projects Birdcall and Short Order, General LeMay was impatient for flight verification of SSB, and authorized the two flights with ham equipment and contacts. The results set in motion high Collins growth in military SSB equipment and systems, USAF and USN, for many years to come.

Further, this impatience led LeMay to install a network of ground stations in the US, Greenland, England, Africa and Guam, all with Collins SSB ham equipment.

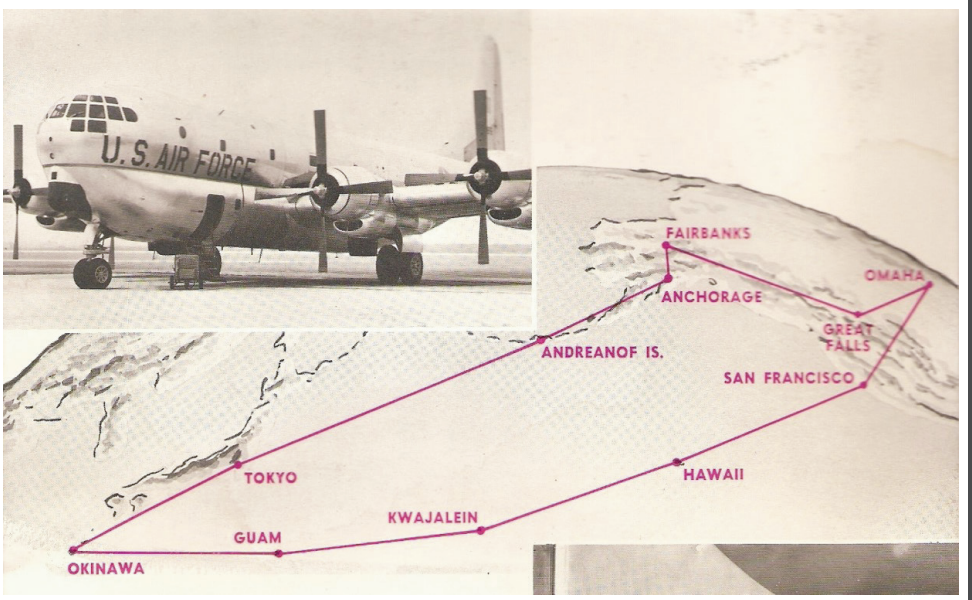



Figure 6: Flight 1 Route

This expedient served SAC well until project Birdcall would install the high-power transmitters, antennas, and other equipment for a complete Mil site.

Typical SAC ground stations would have three Collins 45 kW 205J PAs and six 10kW 204C PAs. Additionally, they would have huge Wullenweber directional antenna arrays. All of these sites were interconnected by landlines and oceanic cables.

Figure 7: Collins, Grosvenor, and General Griswold

I cannot overemphasize the importance and absolute necessity of multiple ground sites, connected by phone lines, for the success of HF communication with SAC aircraft flying anywhere on the planet. Collins intuitively knew this and set an example with its famous Liberty station at Cedar Rapids. Identical equipment was remotely controlled by land lines to Dallas, TX and Newport Beach, CA stations. Liberty was also connected to the SAC phone network.

For example, if propagation from Liberty (who was on contract to SAC) to an aircraft was unfavorable, the Cedar operators could change the path by remoting either the Dallas or Newport Beach stations. HF SSB alone was not sufficient. Some path control was essential. I called this "propagation path diversity."

As SAC would build its large HF SSB systems, designed and implemented by Collins, it would always incorporate this principle. In contrast, for decades ARINC HF stations supporting commercial aircraft refused to do this with their gateway stations at New York, Shannon Ireland, San Francisco, etc., with less than satisfactory results. Collins had a heavy influence on SAC to do it right.

Looking back on these events, I'm reminded that without the gutsy leadership of LeMay and Griswold at SAC, and Author Collins at the Radio Company, it's doubtful that there would have been these highly successful SSB communication systems at the right time, at the height of the Cold War.

Competitors attempted it, but never with the performance and reliability of those that Collins designed and implemented.

And to think that it all got accelerated by flying some new Collins SSB ham equipment and contacting a lot of hams! Unorthodox, but effective if you have the right technology and leadership!

## C-97 Restoration and Historic SSB flights Display

Quite by accident, I came in contact with personnel from the Berlin Airlift Historical Foundation, who were unusually interested in the 1956 flights. The BAHF flies a restored C-54, the workhorse of the Berlin Air Lift, to air shows as a museum of that period, with displays inside.

Additionally, they have been restoring a C-97 for 17 years! After countless delays, they finally got her airborne last fall. Figure 8 shows her in flight from Brooklyn to Redding, PA, where she was on display at the famous Redding Air Show this June.

My contacts, all hams, found out about our restoring a working WW2 radio position on the Commemorative Air Force B-29, FiFi. Also, they had studied about the 1956 SSB flights and thought it would be very meaningful to have an onboard, working radio position, virtually identical to that on General Griswold's C-97A.

Further, with posters and props, they would tell this SSB success story to airshow visitors touring the aircraft on the ground, and also operate the ham gear. Would we, the Collins Radio Clubs that had done the FiFi radios, be interested in the 1956 radio position restoration?

Figure 9: The C-97's Cargo Area

To us this was a no-brainer. With FiFi, we could only ham communicate while airborne, and lacked sufficient aircraft space to demonstrate or discuss the radios with air show visitors on the ground. We could easily do this with the C-97's large cargo area as shown in Figure 9.

Additionally, while FiFi could only transmit voice by AM, and had a limited performance BC-348 receiver, the C-97 would transmit SSB and have a high performance 75A-4 receiver, resulting in a much greater ham audience. This would be pure Collins, an extraordinary opportunity. So, we signed on.

The first priority is an airborne HF antenna installation. The Florida firm that donated an antenna kit for FiFi has shipped a similar one though us for the C-97. One of our CCA members, Rod Blocksome, donated a hard-to-find 180S-1 antenna coupler, and a 75A-4. Our urgent need is for a working KWS-1. A second 75A-4 can come later.

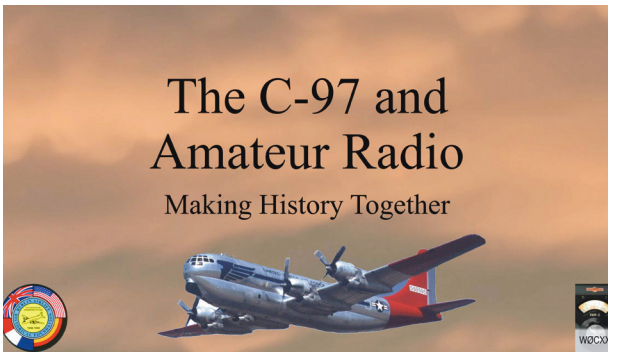
I'm urging our CCA members to help us with this. We at Dallas can do repair on a KWS-1, but not a complete restoration. I'm hoping for a CCA positive response.

The BAHF folks will build the radio position tables, install our tested and working equipment, and install our antenna kit with guidance from a Collins engineer.

At the Redding air show, the BAHF created eleven panels for a large poster explaining to visitors its intentions for the radio position. Space only allows me to show one of them here, but please go to our CCA website, www.collinsradio.org/c97, and scroll down through all of them. They show BAHF's seriousness and are a good pictorial summary of this article.

When the radio position is implemented, this C-97 will be quite a flying museum that will tell a lot about Collins. And we have this opportunity for CCA to help make it happen.


Figure 8, BAHF C-97




Loney Duncan,
W0GZV
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972-562-4404

Loney joined Collins Radio, Cedar Rapids, in 1957. He served in engineering development and line management, becoming a division director of HF Equipment and High Power Transmitters. This division developed the paradigm shift avionics 718U HF transceiver and 651S receiver. Additionally, it developed the 821-A2 second generation 250 kW shortwave broadcast transmitter, and the TACAMO 200 kW airborne VLF (17-30 kHz) transmitter and trailing wire antenna.

In 1976, he joined the corporate engineering staff of Rockwell International who had purchased Collins. He became VP, Electronics Technologies and Processes, reporting to the Chief Engineer of Rockwell. Loney retired in 1998 after almost 41 years with Collins and Rockwell.

# Dayton (Xenia) 2018 Recap

By Scott Kerr, KE1RR

As you know, the Dayton Hamvention moved last year from the Dayton Hara Arena to the Xenia Fairgrounds. The Hamvention Committee did a great job preparing the site but challenges remained - mainly the lack of Vendor space and the drainage of the outside Flea Market area.

This year the Indoor Vendor space was enlarged and they made significant improvements to the Flea Market area - since it always rains during the Hamvention! Even so - there was a waiting list for Indoor Vendors - and the Committee has done a great job of keeping the Vendors Ham Radio focused. A welcome change from the old Hara Arena days.

Hopefully, we will see a return of the huge numbers of Flea Market Vendors. But the declining number of those vendors is not limited to Dayton - this is a symptom of the huge change in Hamfests across the world - eBay and other internet marketing sites has forever changed the landscape of Hamfests. That said, there was still a good representation of Collins equipment out in the Flea Market.


Activity in the Collins booth was brisk, with a never ending line of people asking all sorts of Collins questions and sharing their stories of Military use of Collins or their experiences working for Collins in days gone by. Many of the guys that you hear on the Collins nets either as Net Controls or participants stopped by for an eyeball QSO and took time to sit and chat in the lounge area of the booth. To me, that is the greatest part of Dayton.

The banquet on Friday night was back at the Miami Valley Golf Club, which featured good food and a wonderful presentation by Loney Duncan who shared many of his experiences working at Collins and his subsequent work on FiFi with the Commenorative Air Force (see Loney's article in this issue). I had met Loney several times and actually had toured FiFi's radio room with him several years ago. Having some time to sit and listen to his many stories about the history of Collins Radio while sitting at the booth and then at dinner on Saturday night was a real treat for all of us. Thanks Loney, for taking the time to come to Dayton and we hope to see you back next year!


It was also nice to see Jim Stitzinger healthy and able to attend Dayton. Jim was able to take back the reins of the CCA Presidency over the Dayton weekend and is working diligently to bring us a memorable Cedar Rapids CCA event this August.

Dayton always ends with a Saturday night dinner at Marion's Pizza. It is a time to hang out with the hard core Collins crowd and hear great stories of what everyone has done through the year and their plans for the coming year. I know that many of us are planning a trip to Cedar Rapids in August and some of the group had to make the hard decision as to which event to attend this year. It is looking like we will have a really good turnout for Cedar. Hope to see you there!!

# Voltmeter Calibrator

By Don Jackson, W5QN

## Introduction

A couple of months ago, my HP-410B VTVM was acting up a bit, so I decided to calibrate it. For those of you not familiar with the HP-410B, it (or the more modern HP-410C) is the recommended VTVM for maintaining our vintage Collins equipment. Designed for use with vacuum tube radios, it has some special capabilities not available in most modern DVMs. Notable is an extremely high DC input impedance of 122 MegOhms that allows accurate measurement of DC grid voltages and voltages in high impedance AGC circuitry. Another unique feature is the ability to measure AC signals up to 700 MHz using its AC probe that has only 1.5pF of input capacitance. Features such as these make the HP-410B/C highly desirable even today, especially given the relatively low cost of these meters.

DC calibration of the HP-410B is fairly straightforward, requiring only a single precise 1 VDC source. AC calibration, however, is a different story because there are separate adjustment pots for each of the 1, 3, 10, 30, 100, and 300 Volt ranges. After researching commercial meter calibration instruments, it became apparent that they fall into two categories: virtually unobtainable and/or too expensive for my taste. So, I started thinking about how I might build one.

Figure 1: Gene Senti using the HP-410B

## Technical Requirements

The accuracy spec for the HP-410B is ±3% of full scale, so a goal for the Calibrator is accuracy at least 10 times better than that.

Another consideration is the crest factor of the AC output signal. The crest factor is the ratio of the signal's peak voltage to its RMS value. This needs to be considered because most modern meters use RMS detectors, so the time domain waveform isn't terribly important. The HP-410B, however, uses a peak detector in its AC probe even though the meter face indicates RMS. The bottom line is that if the Calibrator is to be accurate for measurement of both types of voltmeters, the calibrating signal should have a crest factor as close to the ideal value of 1.414 as is practical. There is no direct correlation between crest factor and total harmonic distortion (THD), but an estimate would be that the Calibrator AC signal should have THD better than 0.1%.

The frequency of the Calibrator AC output should be well within the "flat" passband of most any bench AC voltmeter. I chose a frequency of 1 kHz.

Although the initial Calibrator was designed to solve the AC voltage calibration issue with the HP-410B, it became obvious that it would not be difficult to add DC output voltages to the Calibrator's capabilities. Therefore, the design was modified to produce 10, 30, 100 and 300 VDC as well as the AC outputs. A front panel switch selects AC or DC output.

## Design Approach

I decided to use an integrated RMS-to-DC converter IC as the basic detector in the Calibrator. The concept is to feed the Calibrator unit with a low distortion audio generator at a level of 1V RMS at 1 kHz frequency. The generator should be capable of low distortion, and have a fine amplitude adjustment capability such as is available on the HP-652A. A simplified block diagram of the Calibrator is shown in Figure 2.

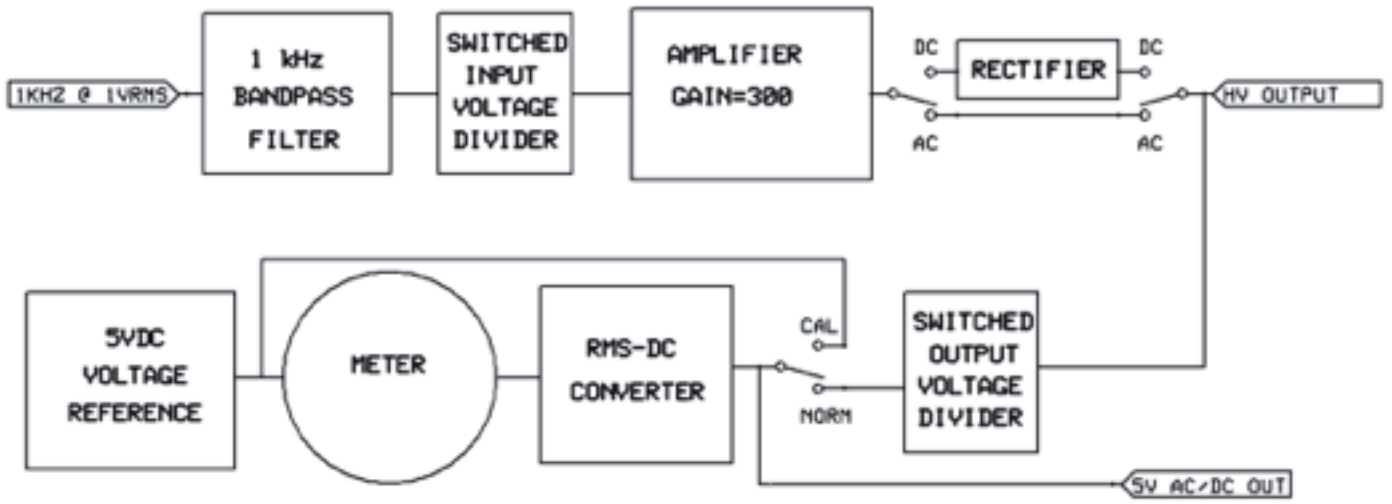



Figure 2: Simplified Calibrator Block Diagram

Input from the audio generator is applied to a passive LC bandpass filter to improve the distortion performance of the audio signal generator. If an audio generator is available with sufficiently low distortion, this filter may not be necessary. I chose a precision audio inductor with no magnetic core to ensure the filter would introduce negligible distortion. This inductor is pretty large and heavy (see Figure 4), so I'd suggest you experiment with inductors with iron cores, testing to ensure they do not add distortion. A problem I had with this particular inductor is that its Q decreased noticeably when mounted in the aluminum enclosure. I added some mu-metal shielding to minimize this problem. My Calibrator is designed for use with an audio generator that has a source impedance of 600 Ohms. The Calibrator input impedance is set to about 600 Ohms by the Q of the inductor in parallel with the input resistive divider network. With a 600 Ohm generator connected, the 3dB bandwidth of the filter is about 120 Hz and the center frequency is about 1.03 kHz. Having the generator precisely centered in the passband isn't necessary.

A simpler and better design approach is to procure an audio generator that has THD better than the distortion of the Calibrator amplifier. My HP652A (1% THD maximum spec) did not meet that requirement so I added the filter. With a much lower distortion generator (preferably with 50 Ohm output), the bandpass filter can be eliminated from the design, and the bandpass filter replaced with a 50 Ohm resistor. Another possibility is the use of your computer sound card and software to generate the 1 kHz signal. It needs to be low distortion at 1 VRMS and have vernier amplitude adjustment capability. My sound card with Spectrum Lab software outputs a sufficiently low distortion signal, but the level is only .25 VRMS, and is adjustable in only 1dB steps. Nevertheless, other sound cards and software might work, and is a possibility worth investigating.

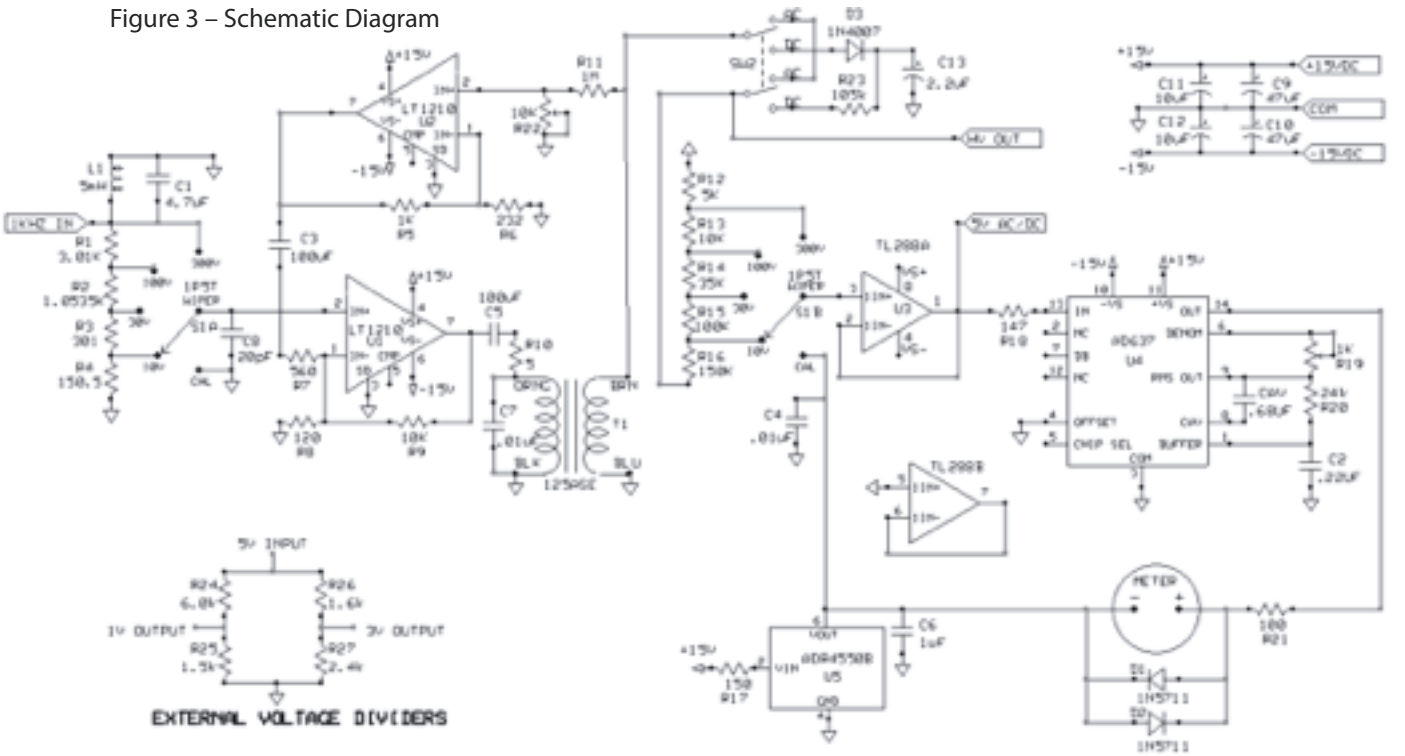
The amplifier stage is constructed with power op-amps (LT1210) and a step-up audio transformer. Approximately 25dB of negative feedback is used to stabilize the voltage gain, and reduce distortion. Total closed loop voltage gain of the amplifier is 300, which provides the amplification necessary to produce the 300V RMS maximum output with a 1 VRMS input from the audio generator. The closed loop voltage gain can be adjusted with potentiometer R22 which sets the feedback level.

At the input and output of the amplifier are resistive voltage divider strings that are switched by the rotary voltage selector switch. These divider strings are designed such that for any output voltage selected, a 5V RMS signal is presented to the input of the RMS-DC detector circuitry. The output of the detector is connected to one terminal of the front panel meter, while the other side of the panel meter is connected to a precision 5V DC reference (ADR4550B), which has an accuracy of ±.02%. Therefore, by fine adjustment of the audio generator amplitude, the Calibrator output level can be manually "locked" to the 5VDC reference.

DC output is generated with a simple peak detecting rectifier that can be switched into the circuit between the amplifier and the HV output port. Accuracy of the DC output is at least as good as the AC output.

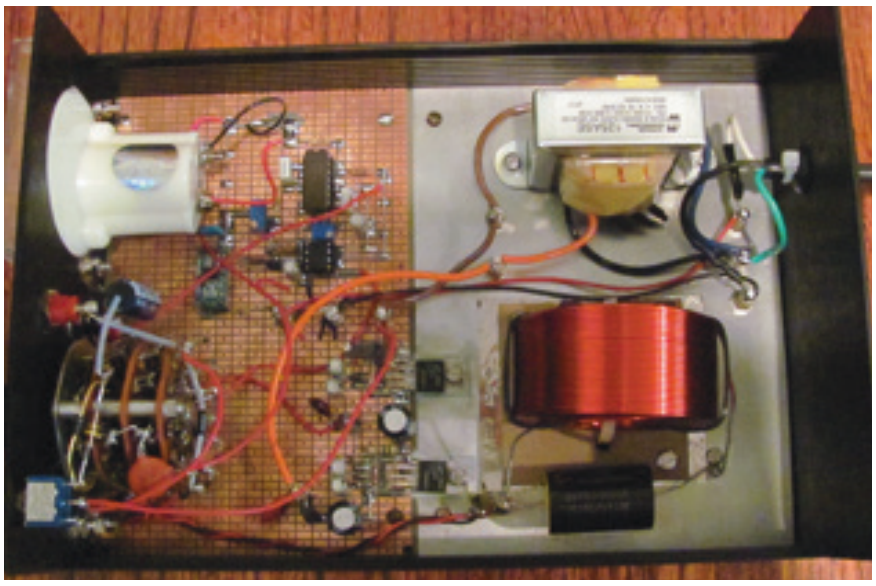
A schematic of the Calibrator is shown in Figure 3. All "ground" symbols are electrically connected to the enclosure chassis. Also, note that the COM port is also grounded to the chassis.

Figure 3 – Schematic Diagram




## Construction

This project was initially planned for my own use, and is not to be confused with commercial gear! Just thought I'd throw that caveat out there. For anyone who decides to build a similar unit I'd be happy to help with details. I did not have a commercial PCB constructed for this unit, but it certainly would have been a much easier build if I had one. ICs U3 and U4 are installed in IC sockets. U5 is available in SMT versions only. Figure 4 shows the internal layout of my Calibrator, but the layout and heatsink concept is up to the designer.



The enclosure I chose is a "clam-shell" design from Context Engineering with grooves for PCBs to be installed. Rather than use a commercially manufactured PCB, the electronics is constructed on a prototype surface mount board. Fastened to this board is a 1/16 inch thick aluminum plate that performs the dual functions of handling the weight of the transformer and input filter inductor, as well as providing a heatsink for the two LT1210 op-amps.

LEFT Figure 4 – Internal Component Layout

With this arrangement, the LT1210 op-amps barely get warm, even when the amplifier is supplying 300V RMS or 300VDC. The PCB/aluminum plate assembly is fastened to the front panel with a bracket. This construction makes it easy to slide the front panel/PCB assembly right out of the enclosure.

One thing I discovered the hard way is that carbon composition resistors can be a bit non-linear at high voltages, adding to the distortion of the output sine wave. Be sure to use modern film resistors.

## Internal Adjustments

There are two internal adjustments: 1) scale factor, and 2) amplifier voltage gain.

Scale Factor:
1. Set the rotary switch to CAL and apply power to the Calibrator.
2. Set the panel meter to exactly zero reading by adjusting potentiometer R19.

## Voltage Gain Adjustment:

1. With power to the Calibrator off, place the rotary switch in the 10V position and mode to AC.
2. Connect the audio generator (600 Ohm output port) to the Calibrator input and set its output to 1VRMS.
3. Apply power to the Calibrator, and adjust the audio generator frequency for maximum on the panel meter.
4. Using R22, zero the panel meter reading.

These settings are very stable and should not require adjustment. It should be noted that I originally included a DC offset adjustment circuit as described in the AD637K datasheet. However, in the process of testing I found this circuitry produced little measureable improvement. Therefore, I eliminated it and used the standard configuration described in the datasheet. Originally, U3B was used in the offset circuitry, but now it is now longer required.

## Operation

Figure 5 shows the front panel of the Calibrator.

The CAL mode connects the 5VDC reference to the RMS-DC converter circuitry. (Note that the TL288 buffer introduces a rather insignificant error of about .3mV, or .006% .) In this mode, the meter should read exactly zero. If it doesn't, readjust the Scale Factor potentiometer R19. When in CAL mode, a precision 5VDC is available at the front panel "5V AC/DC" banana jack port.

The 10, 30, 100, and 300 volt outputs are available at the High Voltage (HV) banana jack. Please note the HV port is named that for a reason. 300V is not something to be trifled with!


Figure 5: Front Panel

Connect the 1 kHz, 1V RMS source to the Calibrator. This should be done prior to applying power to the Calibrator, or the panel meter will be hard-pinned in the negative direction. After connecting the audio generator, apply power to the Calibrator. Connect the voltmeter to be calibrated across the HV and COM ports. This should be done prior to zeroing the panel meter since there may be a slight loading affect if the voltmeter input impedance is less than 10MegOhms. (I know for a fact that the Keysight 3458A voltmeter with an AC input impedance of 1MegOhm in parallel with 140pF will drop the HV output by about 0.1%.) This loading affect is more noticeable in DC mode, since the rectifier circuit has a higher source impedance than when in AC mode. Select AC or DC mode and the desired output voltage. Fine-tune the audio generator output amplitude for zero reading on the panel meter. Each minor division on the panel meter face (5uA) translates to an output voltage variation of about 0.1%.

Figure 6: External 1V/3V Divider Assembly

When ANY output voltage is selected, 5V (AC or DC depending on the mode selected) is available at the "5V AC/DC" port. Connecting a precision resistive voltage divider assembly to this port produces the 1 Volt and 3 Volt outputs. Note that you can also obtain precision 1 VDC and 3 VDC with these dividers when in the CAL mode. Figure 6 is a photo of the external resistive divider assembly.

A handy method of connecting a voltmeter to the Calibrator is a bit problematic since there is a lot of variation in voltmeter probe construction. Although not elegant, I use a couple of short banana plug to alligator cables for this purpose. This works fine at 1 kHz, and allows for connection to a wide variety of probes. Of course, if the voltmeter has banana jack inputs, use banana plug to banana plug cables.

I have not performed a detailed analysis of the amplifier stability. The LT1210 op-amp has a very wide bandwidth, so it is possible that there is some reactive load on the HV port that could result in oscillation. I observed some oscillation around 70MHz during initial testing, which was eliminated with the addition of C7 and C8.

## Accuracy

Although I have no way to measure crest factor directly, I calculated Calibrator THD by measuring the 2nd and 3rd harmonics (the only ones visible) with my Spectrum Lab audio analyzer. Using the "square root of the sum of the squares" method, I found the THD to be about .01%, which I believe is satisfactory.

Theoretically, the accuracy of the Calibrator is based on just three component accuracies: the tolerance of the output voltage divider resistors (0.1%), the accuracy of the AD637K (.055%), and the accuracy of the ADR4550B (.02%). If all these tolerances add up in a worst-case scenario, the result is .275%. (worst-case must assume that the resistors include +0.1% and -0.1% units)

The Calibrator outputs were measured at Certified Test Equipment (CTE), a local calibration company in the Dallas, TX area. The test equipment used was a Keysight 3458A. The results were that all the Calibrator output voltages fell within a .07% to .17% window.

In addition, CTE measured the 5V AC/DC port levels to be:
5.0008 VDC (CAL mode – this is the output of the ADR4550B reference)
4.99936 VRMS (AC output mode – essentially the same regardless of selected output voltage)

These results certainly satisfy my accuracy requirements.

## Conclusions and Comments

This unit solves the calibration problem for the HP-410B, and can be used to verify or spot check AC/DC voltage accuracy on many other voltmeters.

My parts cost for this project ran about $220, but this is highly variable based on what is in your junk box. However, the only component from my junk box that was of significant dollar value was the rotary switch, so I believe you should be able to build this unit for around $250. It would be really great to design a PCB for the unit, but this would increase cost considerably.

The question of the THD required to maintain a crest factor that will not affect the accuracy of HP-410B calibration remained, so I performed an experiment. With the input LC filter installed, the THD of the Calibrator AC signal was measured to be about 0.01%. With the LC filter disconnected, the THD rose to about 0.2%. I measured the HV output (100 Volt AC setting) with my Fluke DVM and with the HP-410B under both conditions. The Fluke measured the same voltage (to 4 significant digits), as expected, since both the Fluke and Calibrator use RMS detectors. I also found that the readings obtained on the HP-410B were the same (within analog eyeball limits) with either level of THD. So, at least for my HP-652A audio generator, the increased THD did not affect the crest factor from a practical standpoint. This test indicates that I could remove the LC filter, and replace it with a resistance approximately equal to the audio generator source impedance, and the results would be quite acceptable for calibrating the HP-410B. I'll probably leave the filter installed, however, since it is already there.

When switching modes and/or output voltage range, there is a time required for the meter to settle. By far, the longest settling time is in DC mode, when the voltage range is switched from a higher to a lower setting. C13 is responsible for this, and there is a tradeoff between settling time and ripple on the DC output. A bit of experimentation indicated that a value for C13 of 2.2 uF was a reasonable choice. With this value, the worst-case meter settling time was about 1 second, and the peak-to-peak ripple was measured at about .15% of the DC output.

In retrospect, if I were building this unit again, I'd choose the ADR4530B (3VDC with .02% accuracy) voltage reference. This would require adding a 3 Volt rotary switch position and changing the resistor values for the input and output voltage divider strings. You would then only need one external voltage divider to generate the 1 Volt output. It would be nice to use a 1 VDC reference and get rid of any external divider. But, to my knowledge, no one makes a 1 VDC voltage reference with .02% accuracy. If you choose to build this unit and want to use a 3 VDC reference, let me know since I have a spread sheet that will generate values for the input and output divider strings.

Power to this unit is ±15VDC at about 50mA. The current draw rises to about 150mA when the Calibrator is supplying 300 Volts.

The reason for this is not because the Calibrator needs to supply more output power to the output divider string, but is a result of the transformer primary winding having insufficient inductance. (approximately 4mH primary and 10H secondary for the Hammond 125ASE). Although this transformer functions satisfactorily, less DC supply current would be drawn if its inductance were several times larger. Of course, such a transformer will typically be considerably larger and heavier.

A possible future enhancement to this design might be adding an automatic leveling control (ALC) to eliminate the necessity of manually "zeroing" the meter. ALC requires identification of a suitable low distortion electronically controlled audio attenuator. Another possibility would be to replace the external audio generator with an internal generator. Projects for another day!

One final reminder: This unit has outputs of 100 Volts and 300 Volts. Take care with these potentially dangerous voltages!

Drop me an email if you get serious about building one of these. I'll be happy to answer questions. Special thanks to Bob Jefferis, KF6BC, for his critique and suggestions. Thanks Bob!

Cheers,
Don, W5QN

# In The Shack with Wayne Heil, KB6OQJ


I got my Tech license in 1961 at age 13. My call was WA2UXG. I was living in Western New York at the time not too far from Buffalo. I didn't have an Elmer so I never got a station set up. My dad's neighbor was a ham so once I went to his house and he let me see his station and take part in a QSO or two. I don't remember what his transmitter was but I do remember that the receiver was a Collins 75A-4. Love at first sight. Anyhow, I went into the Air Force in 1965 and let my license lapse. After my Air Force tour (most of which was a Vandenberg AFB) I moved back east for a year before enrolling at UC Santa Barbara and returning to the Santa Barbara area. I graduated with a BS in Computer Science in June 1978.

During the summer between junior and senior year I took a part time job as a real time system software engineer for Comptek Research, a company that had just opened an office in town to work on a contract with Raytheon. I worked there for 38 years before retiring in 2015. I still work there as a contractor a couple of days a week. My wife enjoys the time off. Around 2000 the company was purchased by Northrop Grumman.

Over the years I morphed from being a systems software engineer to a true systems engineer responsible for design, implementation, and integration of embedded real time systems.

In the mid 80's, a coworker got me interested in ham radio again and I managed to get re-licensed, again as a Tech. I was mostly involved in the area VHF/UHF scene and was active in ARES. Within a couple of years I upgraded to Advanced and eventually to Extra (unfortunately after the code requirement was dropped from 20 wpm).

Maybe around 1990, I picked up a Kenwood TS-440 at a local ham fest and erected a sloper. That got me into HF. Eventually I bought a used Tri-Ex WT-51 tower and a KT-34A antenna. I still use those today.

The next rig was a Yaesu FT-101E. A really nice setup.

In early 2007, I ran across an ad on the Collins Reflector for an S-Line set, a 75S-3C, and the speaker from a ham in the Phoenix, AZ area (Dave Kelly, AI7R). We made a deal but he did not want to ship it because he was of the opinion that even if it's insured, once the radio is gone - it's gone. He had a daughter who lived in the LA area so he drove it out here and we met up at the beach in Ventura. We have been friends ever since. Dave also built my 40/80 CCD antenna.

Some time later I came across a KWM-2 ad on eBay. I was pretty careful about doing an eBay deal and avoided the ads that said "Mint condition, from my personal collection." It turned out to be in pretty decent condition, so now my Collins collection started to grow.

Eventually I got my coveted 75A-4 and later the KWS-1 — a set of Gold Dust Twins! The collection also includes a 32V-2, 75A-1 KWM-1 (needs some work) and an R-390A (Motorola). And by the way, I'm not related to Bob Heil, K9EID, but my 30S-1 came from ex-CCA President the late Sandy Meltzer, KW6KW.


Two Rare KWM-380 Variants: Top — 451S-1, Bottom — HF-380A