Volume 36, Number 1

Spring/Summer 2017

Journal of the

CALIFORNIA HISTORICAL RADIO SOCIETY

FOR THE RESTORATION AND PRESERVATION OF EARLY RADIO

FROM THE BIRTHPLACE OF BROADCASTING

California Historical Radio Society

HOME OF THE BAY AREA RADIO MUSEUM & HALL OF FAME

The California Historical Radio Society (CHRS), is a non-profit educational corporation chartered in the State of California. Formed in 1974, CHRS promotes the restoration and preservation of early radio and broadcasting. Our goal is to enable the exchange of information on the history of radio, particularly in the West, with emphasis on collecting, preserving, and displaying early equipment, literature, and programs. Yearly membership is $30 ($40 non-USA).

CHRS Museum in Alameda

CHRS has been fortunate to through the generosity of its donors to purchase a home for the CHRS museum and education center. It is located at 2152 Central Avenue. The building was built in 1900 as a telephone exchange.

CHRS volunteers are actively restoring the building to make it optimal for use. Our goal is to create an environment to share our knowledge and love of radio and enable us to create an appreciation and understanding for a new generation of antique radio collectors and historians.

◊

Contact us:

CHRS, PO Box 31659, San Francisco, CA 94131
or info@californiahistoricalradio.com

Visit us at: www.CaliforniaHistoricalRadio.com

Officers & Directors

Mike Adams – Chairman, Webmaster
Steve Kushman – President, Radio Central Project Manager
Scott Robinson – Vice President, Technical Ops.
Jamie Arbona – Secretary, Mailing
Richard Watts – Treasurer, Membership, Publications, Collections
Tom Bonomo – Name Badges
Philip Monego – Director at Large
Dennis Monticelli – Education

W6CF Trustee, John Staples, W6BM

CHRS Central Valley Chapter

Eddie Enrique – Chairman

Staff

Walt Hayden – Radio Central Planning Consultant Manager, Building Operations
Larry Drees – Manager, Landscaping Operations
Butch McDonald – Asst. Manager, Landscaping Ops.
Bart Lee – Counsel Emeritus, Hist., Archivist
Len Shapiro – BARM Executive Director
John Stuart – Systems Consultant, Networks, and CAD Drawings
Dave Billeci – Video Production
Paul Shinn – Amateur Radio Operations
David Vasquez – Electrical Transcription Project
Larry Clark – Technical Advisor & Librarian

Contents of the Journal

Front Cover: Cover of the December 1927 issue of the *Science and Invention* magazine.

Rear Cover: Images of various recent CHRS activities.

From the Editor

This issue offers a look at the Iconoscope and John Staples efforts to make it operational, a rare feat as only three other operational Iconoscope cameras are known to exist. Then Dick Singer tells us of his time in the Global Explorer as it attempts to raise a sunken Soviet submarine in the 1960's. And finally I provide the highlights of the accomplishments of Leon Theremin and the Theremin, one of the first musical instruments developed from radio engineering. Once again I've had the pleasure of working with very generous and capable contributors. I want to thank Dick Singer of the Society of Wireless Pioneers and now CHRS, John Staples, Walter Hayden, Scott Scheidt, and Steve Kushman.

I am always in need of quality content related to broadcast radio, ham radio, and television. If you have something to contribute, I urge you to let me know. I am especially interested in technical content. It can be of two types, a narrow topic in depth or a more broad topic with less depth. Enjoy . . .

Richard Watts, jrchrs@comcast.net

◊

From The President

by Steve Kushman

SOME THOUGHTS ABOUT WHO WE ARE AND WHAT WE DO… CHRS as many organizations, is comprised of people drawn together by similar interests and ideas. Our unique group is attracted to this specialized organization by our love of radio… in its many forms. We appreciate the technology from the earliest crystal sets and spark transmitters to vacuum tubes and solid-state devices. And the hardware that these technologies have produced… Well, we marvel at the style and beauty of these devices; these tools of modern communication; with an almost limitless range of types, shapes, designs, colors, materials, functions and sound quality that have been an integral part of our lives and fixtures in our homes for over 100 years. We embrace the eventful history of communication development and are aware of the importance of imparting this fascinating radio history on new generations. We study and teach the origins and the restoration and repair skills necessary to keep these sometimes antique artifacts of our past doing what they have been doing for over a century… Bringing music, entertainment, sports, news, information and communications during times of peace and war into our homes and businesses, our cars, at the beach or anywhere else one could have a radio.

We tell the story of radio but it's just half the story if we address only the 'radios' themselves. We touch the radio to turn it on and tune it in. The sounds and ideas that emerge from the radio touch us, sometimes turn us on and always keep us tuned in. Radio broadcasting has been a routine part of millions of lives for over 100 years and we appreciate its importance and the effect it has had on our modern civilization. We're fortunate to have the Bay Area Radio Museum on-line as part of CHRS, www.BayAreaRadio.org. On this site we celebrate the lives and histories of the radio people and the radio stations. And, we present the sounds of thousands of local historical audio clips that have made Bay Area radio second to none.

Our goal is all about preserving the history of all aspects of radio. Why do we do this? Why do we care about this arcane technology understood by few and radio broadcasting, understood by many? I have always been taught and firmly believe that man is a curious creature. This curiosity as it pertains to history if pursued, leads to increased knowledge and the personal satisfaction of learning… how and why. In today's fast paced, highly advanced technical society, most people take wireless communication for granted. Few know or care about the simple wireless technology of the late 1800's and early 1900's that grew and developed through the century. It was the cornerstone of the sophisticated wireless of today. To quote Director Denny Monticelli, "Radio in the 20th Century was as important as the Internet is in the 21st Century." CHRS cares, and we are pleased to provide opportunities that allow us to present the stories of radio; to make sure people appreciate and understand how today's radio, TV, internet and personal communication came to be; to honor the many radio pioneers, inventors to broadcasters, who enriched our lives by introducing radio into society; to pass on the knowledge and skills to perpetuate the preservation of radio and, to introduce and foster enthusiasm in new generations for the appreciation and importance of radio and broadcasting. We are hopeful that this new generation, as we do, will realize the importance of our work and will ensure CHRS' mission is carried well into the future.

The attainment of our goal requires dedication and passion. CHRS is blessed to have dedicated and passionate people who constantly strive to make sure we succeed. We place high value on our efforts for historical preservation, presentation and education. We are collectors, historians, craftsmen, technicians, teachers, restorers, preservationists, researchers, organizers and philanthropists who contribute high skills, knowledge and resources to CHRS. All work hard to ensure that radio is not forgotten in the annals of time.

We come from all walks of life and bring unique perspectives and personalities into our CHRS Family. And it really does feel like a family when we all work together, take a break and share a nice lunch together on volunteer days. Some of our Family members consider Radio Central their second home and enjoy coming week after week to help improve our 117-year-old building, to volunteer for other projects and to enjoy the camaraderie of a great bunch of people. It's a Family that makes up the crews for our events, donation pick-ups and retail sales events. I have said for many years that our volunteers are the engine that drives CHRS. That is true even more now that we own Radio Central. Our CHRS Family takes immense pride in the fact that we are one of perhaps only a handful of vintage radio societies that has been able to raise enough capital to buy our own building. It's hard for me to express how lucky and grateful we are to be able to share our common interests and be part of this special CHRS Family. So, I hope I have cast a good bright light on who we are and what we do… It's all Good! And I will repeat again how honored and proud I am to be associated with such a fine group of people.

HEADLINES… Radio Central Flood Causes Renovation Plans To Change. No Artifacts Lost. Minimal Permanent Damage. Concerned Citizens Donate Almost $100,000 Toward Water Intrusion Control Project… $50K Still Needed.

Big Year For, "The San Francisco Radio Station That Changed The World – KSAN Jive 95: The Movie." Production Continues. Custom Version Screenings in June for 50th Anniversary of Summer Of Love and on July 22nd at "Radio Day By The Bay 2017." Stay Tuned. Major Funding Still Needed to Complete Documentary. Executive Producer Position Available.

Retail Outlets For CHRS Restored Radios Very Successful. 1950s & '60s Sets Selling Like Hotcakes. iPod Wire & Bluetooth a Plus. Alameda Antiques Fair Yields Over $3,000. Over 90% of Radios Sold. Buyers Are 'Young' and Want an 'Antique' Device In Their Home.

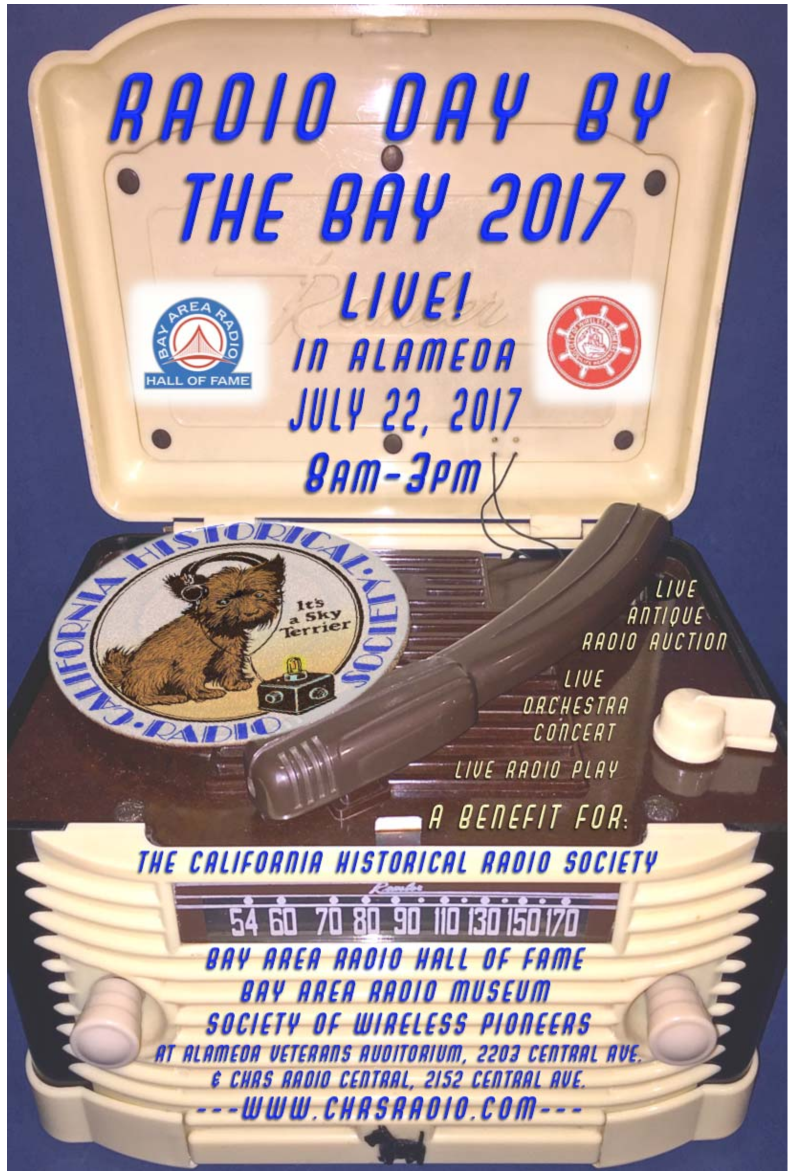
KLIV San Jose Named Legendary Station for 2017. New Voting Procedure for Bay Area Radio Hall Of Fame. First Year for the Don Sherwood Award. BARHOF Inductees Announced July 22nd at "Radio Day 2017." See www.BayAreaRadio.org for Details.

I am out of space. Be sure to enjoy this excellent Journal. Thank You Richard for another terrific edition! Please feel free to contact me with your comments, questions or just to say hi.

Best Regards,

Steve (415) 203-2747 or Steve@chrsradio.com .

◊



CHRS Central Valley Chapter News

by Scott Scheidt

The CVC Annual Luncheon was held on January 7, 2017 at Las Casuelas in Turlock. After a nice meal and radio related conversation, Scott Scheidt was presented with the annual CVC "Western Air Award". This award is given annually by the CVC in recognition of a members who provide outstanding service and contribution to the CVC organization. He was recognized for his duties as club secretary, organizing monthly meetings, notifying the membership of club events, and maintaining the CVC website.

The annual CVC Model A Swap Meet was held in Turlock on January 28th and 29th, 2017. This is a major car show and sale with thousands of people in attendance. This gives significant public exposure of CHRS, CVC, and vintage radio. We also provide radios for sale and respond to radio repair requests.

CVC offers a weekly radio theory and repair class. CVC also continues to offer the Radio Repair Clinic every Wednesday, 6-8 PM. Membership meetings are held on the 3rd Saturday every month at 10:30 AM. Our meetings are at the clubhouse at the corner of Bradbury and Commons just Southwest of Turlock.

◊

Radio Central Renovation Update

by Walter Hayden

Original circa 1900 exterior front elevation of 2152 Central Ave.

Electronics Shop: Construction in the electronics shop is finished. Floor tile, baseboard molding, T-bar ceiling, LED lighting, utility sink and workbench power system were completed in the last part of 2016. Workbenches are now installed and populated with test equipment. Parts cabinets and equipment shelving have been moved into the shop. Electronics ship is now being actively used for radio repair.

Building Rear Stairs: A custom made all metal stairway was delivered and installed at the Electronics Shop rear door. This is a very sturdy and durable stairway with two landing platforms. It is wide enough that large radios and electronic equipment can be easily transported into the shop.

Tube Room: Construction is complete. A new concrete floor was poured on top of the existing damaged floor. Tube Room floor now is same height as adjacent hallway floor to provide a smooth entry. A custom made adjustable shelving system was installed in the Tube Room. To minimize wasted space Unistrut is used for shelving support. The shelving system was designed to maximize tube storage space. A new cover was made for the Tube Room sump. A small workbench was added to provide space for tube testing and sorting. Tube Room has new ceiling mounted fluorescent lighting. The room is fully functional and is being used for tube storage.

Downstairs Gallery: Work has begun to renovate the downstairs gallery space. Interior non load bearing walls and wall covering on the exterior brick wall have been removed. Old carpet and linoleum floor coverings have also been removed. The condition of the 100-year old floor and walls is being assessed and a path forward is being determined.

The Masters... Larry Drees, Robert Swart, Cliff Farwell, Walt Hayden, and Kevin Payne (not shown) with help from others are the builders of many projects at Radio Central.

We absolutely have the best volunteers — We cannot thank them enough!!! ◊

The Iconoscope TV Camera at W6BM, Berkeley

By John Staples, W6BM

1. Background

The mechanical television era, dating from the early 1920's, used mechanical scanning technologies (discs, lenses and mirrors) to rasterize the subject with resolution from 30 lines, 12.5 frames per second, ultimately to 240 lines, 50 progressive frames per second by the middle '30's. The scanning can proceed from left-to-right, or from top-to-down, as in the original Baird system. Each scan line comprises 30 to hundreds of pixels, which defines the resolution in the direction of the scan line.

As each pixel element in the scene is scanned by one-by-one, the time exposure of each element is only the short time the scanner dwells on that pixel, requiring a high scene illumination.

If all the pixel elements of the scene can be stored in parallel, say on a 2-dimensional array of capacitors, and then each read out sequentially, the sensitivity is significantly increased. This is the basis of the iconoscope image pickup tube which stores the image on a mosaic plate of millions of individual small photosensitive capacitors which charge up individually according to the brightness distribution of the screen.

I acquired an RCA 1850A iconoscope 20 years ago from Al Jones, the founding president of the Tube Collectors Association. It was time to put this valuable tube to work in a camera, joining three known operational iconoscope ("ike") cameras in the world. Below I report on my decisions and technical progress in this successful endeavor.

The iconoscope camera in operation.

2. Construction

My goal was to produce a working camera with construction techniques that I could easily master. The camera body is fabricated of 3/4" plywood, easier for me to work with than an all-metal box which would also have easily provided the required RF shielding.

Should I use more authentic (for the '30's) vacuum-tube electronics, or go solid-state? Solid-state won out, particularly for the video circuits, as wide-band amplification is much easier to accomplish with wide-band op-amps. Also, except for the iconoscope high-voltage circuits, all DC voltages are safely less than 12 volts.

The individual circuit modules (video, deflection, power) would be constructed separately so they could be debugged easily. Most of the electronics was constructed on a protoboard, as many circuit variations were tried until a successful one was found. Then, the circuits were rebuilt on 0.1 inch perf boards and packaged in small enclosures with connectors for the cables.

As many of the components as possible would come from my extensive junk box, some of them unlabeled transistors and FETs, which were characterized on a curve tracer, so the circuit diagram does not contain type numbers for some of the components.

Should the sync be full NTSC, or just random interlace for a 525-line picture? The current choice is random interlace scanning, so the video image cannot be captured on a video recorder. I have three NTSC sync generators, and it would be not too difficult to substitute them for the present sync generators, but it would add to the bulk of the system and hamper the portability of the equipment. That may come later.

The lens is probably from an old photocopy machine and is well-suited to the camera. It is a 2 inch, f/4 flat-field lens with an 8.5 inch focal length, with no adjustable iris. A fast lens is required, as the sensitivity of the camera is still low compared to modern cameras, and the scene requires a high level of illumination. Sunny outdoor scenes are fine, but indoor incandescent-lit scenes require a lot of light.

3. Iconoscope Tube

To increase the sensitivity of image pickup devices, the storage principle was invented. V. K. Zworykin, who first studied TV technology in his native Russia, then in the USA, mostly at RCA, developed the iconoscope tube in the late '20's as a high sensitivity (at that time) storage– principle image tube for high definition (at that time) television.

The RCA 1850A iconoscope tube.

A lens focuses the scene on the mosaic, about the size of an index card, which consists of millions of small separate silver globules on an insulating mica substrate. The globules are treated with cesium, which renders them photosensitive, so they will emit photoelectrons when hit by light and thereby charge up. Behind the mica substrate is a full-size signal plate, connected to the video amplifier.

An electron beam scans across the mosaic, and recharges each small globule that has lost electrons, causing a signal to be capacitively coupled to the signal plate, generating the small video signal.

The actual operation is much more complex than this, which reduces the sensitivity of the iconoscope to 5% of its theoretical value, but the gain in sensitivity is enough to make the tube practical for the advent of fully electronic television.

Experimental television broadcasts in the US used iconoscope tubes up to the war, and were replaced by the superior orthicon tubes after, with the iconoscope still used in the late '40's for film pick-up.

Another tube, the image dissector, was invented in the '30's by Farnsworth, which was a non-storage tube, but with the addition of a secondary-emission signal amplifier, could produce good quality pictures, but still lacked the sensitivity to make live electronic television practical with it.

4. Design

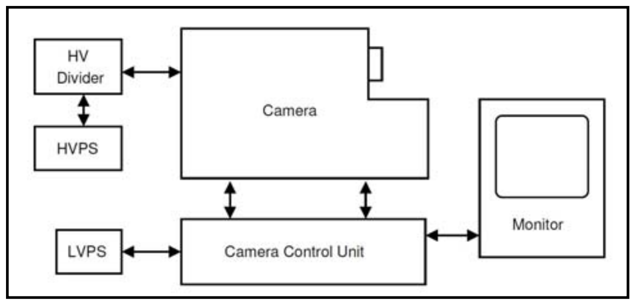
Due to the small magnitude of the video signal, the iconoscope must be fully shielded from outside interference. Broadcast stations in the 1 MHz band would produce strong interference in the image signal.

The camera body is wood, which is fully lined on the interior with a copper screen Faraday shield. All connections to the camera pass through connectors fitted with RF bypass capacitors.

Only the video preamplifier is inside the camera body. It amplifies video the signal, which is less than 0.1 microampere, at high impedance to a level that can be safely transferred on coax to the video amplifier chain. Also inside the camera housing are the deflection yoke, the high-voltage leads to the iconoscope, and the bias lights, which are used to put a uniform illumination on the mosaic which has an effect on the sensitivity and spurious signals (shading) of the iconoscope.

The iconoscope tube itself is wrapped with an aluminum foil shield to further prevent electrical interference from the deflection yoke from entering the tube. Shielding turned out to be the most difficult issue to solve satisfactorily, as the overall video gain is so high, the signal is so weak, and the bandwidth so large.

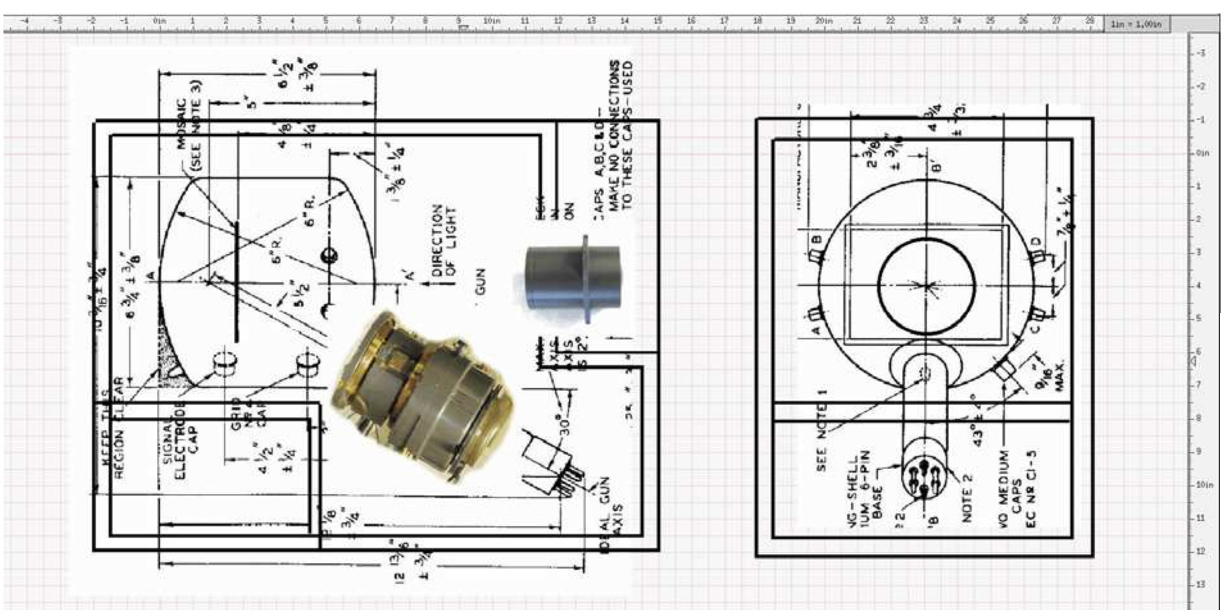
The circuitry external to the camera body is broken up into individual modules: camera body itself with video preamp, the video amplifier, the deflection circuits, the 1-kV HV divider chain for the iconoscope tube, and the LV and HV power supplies, along with the monitor. All modules are connected with cables and connectors.



Block diagram of the camera components.

5. Camera Body

The camera case is built of ¾ inch plywood, cut from a 2 by 4 foot piece. The camera case pieces are joined by internal bracing, so no screws are visible from outside. The figure shows the outline of the wooden case around the iconoscope, the lens and the deflection yoke, viewed from the side and from the front. The iconoscope sits on a “boat” that secures it with nylon straps to a form-fitting cradle. The cradle sits on a shelf and is attached with long bolts with wing-nuts to allow a coarse positioning of the iconoscope.



Plan for the camera body.

The entire case is Faraday-shielded with a copper screen completely lining the case, except for the lens opening. All the sections of the screen are connected together, and contact is made to the screen on the removable side through four banana -plug mounting points.

The internal wiring for the deflection yoke and the high voltage to the iconoscope are shielded in braid to prevent radio interference inside the case.

Two DC-operated lamps form the bias light that can flood the mosaic with a uniform low-level light, which has a small effect on the shading signal generated by the iconoscope.

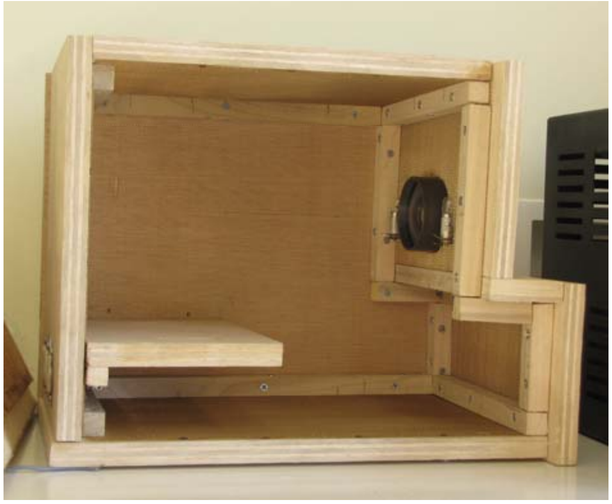
Connections to the outside of the case are through three ceramic octal sockets, where all the non-signal conductors are bypassed to ground by capacitors.


Finished camera case.

6. Lens

The lens is a f/4 flat-field lens with a 8.5 inch focal length. There is no adjustable iris. The lens probably came from an office copier.

The lens has a tight slip-fit to the hole in front of the case and is directly in line with the center of the mosaic. Focus is adjusted by manually moving the lens in the hole of the case. The range of focus is from about 3 feet to infinity.


Interior of the case showing the Faraday shielding.


Iconoscope installed in the case.

7. Iconoscope Circuits

The iconoscope voltages include 6.3 volt AC for the heater, and a 1 kV accelerating voltage between the cathode and the mosaic. The electrostatic focus electrode requires approximately 400 volts, and the control grid (beam electrode) operates up to 100 volts negative to the cathode.

The iconoscope is operated with the mosaic at about ground potential within a few volts, so the heater is near 1 kV negative, requiring a filament transformer with good insulation. The resistive divider is located in a separate box, with the HV introduced through a HV-connector (similar to a BNC). A resistor string drains 2 mA and contains two potentiometers for focus and beam current, on HV standoffs for safety, and indicator lamps for filament (incandescent) and HV (neon) with green and red jewels.

The case has a cover (not shown here) to prevent access to the high potential.

The high voltage is provided by a regulated 0-2 kV Power Designs 2K-10 power supply, that is controllable down to an increment of one volt. The supply is current-limited to 10 mA.

8. Video Preamplifier

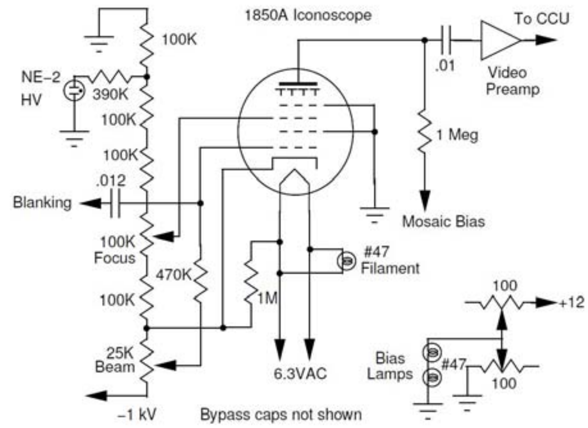
The video preamplifier is the most critical circuit element. The iconoscope video output current is a fraction of a microampere, and must be amplified to the volt level with a bandwidth of several megaHertz.

The choice of the input resistor to the preamp is critical. As the iconoscope is a current source, the voltage developed across the resistor is proportional to the value of the resistor, so a high value will generate a larger voltage into the preamp. However, the distributed capacitance of the mosaic, the wiring, and the input capacitance of the first amplifier stage will form a low-pass filter.

The capacitance is typically 15 pF, so for a total input resistance of 0.5 MegOhm, the corner frequency is around 20 kHz, at which point the frequency response falls at 6 dB per octave above that, or around 40 dB at 4 MHz.

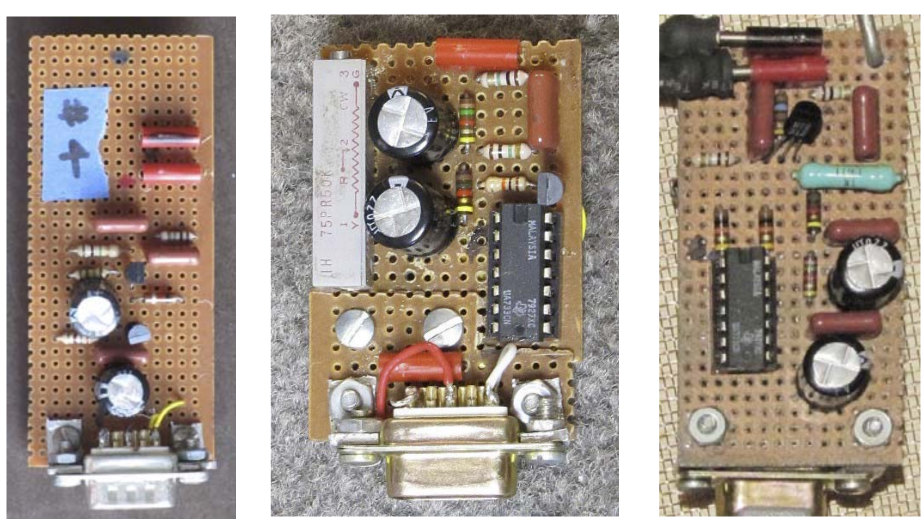
The input resistor also generates a thermal noise (Johnson noise). The voltage is proportional to the square-root of the resistance value, so the signal-to-noise ratio favors a larger resistor value, but the bandwidth favors a lower input resistor. The decision also includes the noise figure of the preamplifier itself, and with a low-noise FET input stage, the value of the input resistor has been chosen to be 0.5 Meg. This resistor is actually two 1 Meg resistors in parallel: one for the input gate of the FET, and the other one in the circuit that allows the bias of the mosaic to be changed to be a few volts of either polarity with respect to the collector ring, which is the ground reference for the iconoscope.

Much of the development effort of the camera is finding a suitable preamp circuit. The preamp is the only active circuit inside the camera body, which was swapped out frequently. To make development easier, several candidate preamps were



The Iconoscope bias circuits.

Box showing the resistive divider and two potentiometers for focus and beam current.



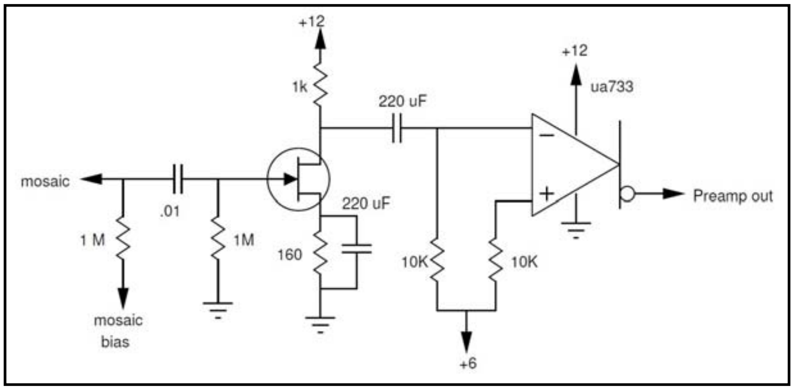
Video preamplifiers:

The left and center are two of the four preliminary prototypes tested.

The one on right is the fifth and final video preamplifier.

built on a small perf board with a DB-9 power and signal connector, and mini-pin jacks for the mosaic and collector terminations to experimentally determine the best circuit.

The preamp configuration chosen for now uses an NTE-312 depletion-mode NPN J-FET in common source configuration with a 1K drain resistor. This FET is a VHF amplifier with a 10 dB power gain at 400 MHz with a 2 dB noise figure at 100 MHz. Even with high-peaking in the video amplifier circuit, the amplifier noise level is acceptably low.



Video preamplifier circuit.

The FET is followed by a ua733 op-amp, which has a frequency response to 200-400 MHz, depending on the gain setting and about a 12 microvolt rms noise level at the input. The input impedance is larger than the 1K FET drain resistor, and it can drive a few hundred ohm load.

The op-amp has both inverting and noninverting inputs, and inverting and non-inverting outputs, which is very useful in determining the proper polarity of the video. The voltage from the iconoscope mosaic is positive-going for black, and the video polarity out of the video chain provides a negative-going black signal.

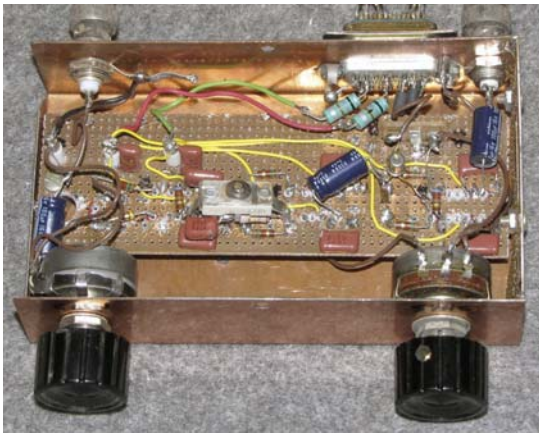
9. Video Chain

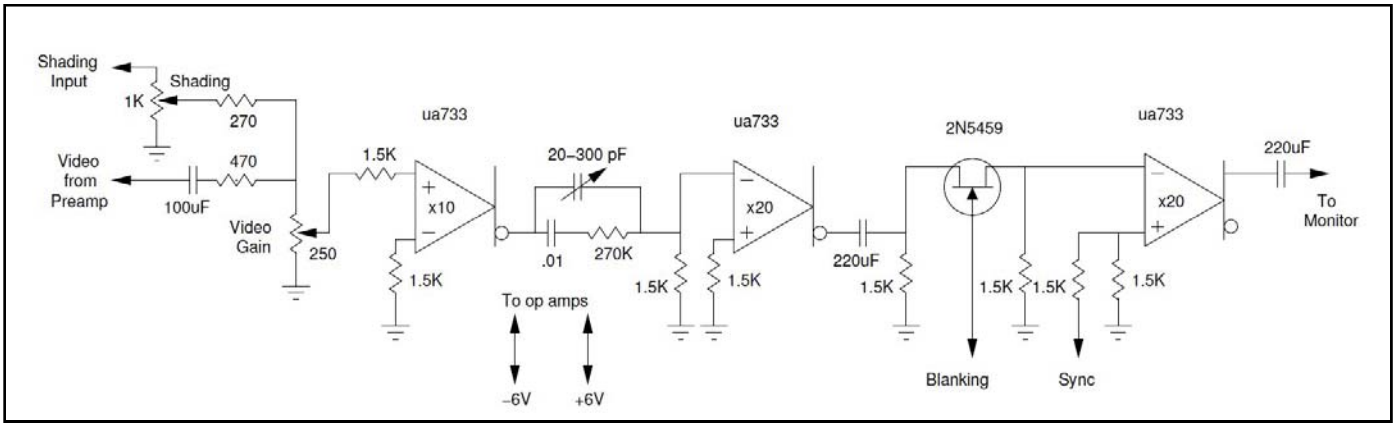
The video chain provides most of the wide-band video amplification, sync , blanking and shading insertion, video frequency response peaking and gain control.

The gain element is the ua733 wide-band op-amp, which provides a flat 200 MHz passband down to DC. Three stages of gain are used, so taming the gain block, along with the design of the preamp, is a most challenging task.

The video amplifier is built on a copper substrate perf board, with all power supply leads bypassed and run through chokes and ferrite beads, with the bypass capacitors soldered directly to the copper substrate.

The amplifier is housed in its own copper-plated box to shield it from outside RF interference. The two knobs are the video gain and sync level. Later, an additional shading level control was added.


Video amplifier housed in a copper-plated box to provide adequate shielding.



Video amplifier circuit.

The voltage gain per stage is adjusted with external gain adjust resistors to be between 10 and 20.

The video from the preamp and the shading generator are mixed together and regulated through the video gain control. At the exit of the first stage the frequency roll-off due to the distributed capacitance at the input of the video amplifier is compensated, with the low-frequency gain below 10 kHz attenuated some 45 dB.

The video signal is amplified by 26 db in the second stage and applied to the blanking gate, a FET that is used as a series switch. The video is further amplified by another 26 dB in the output stage, with the synchronism waveform mixed into the non-inverting input of the output amplifier.

To use a standard video monitor, the video black polarity, as well as the sync tip, is a negative-going signal. The use of the inverting or non-inverting inputs of the op-amps allows the correct polarity of all the signals to be conveniently chosen at each point along the chain. The three amplifiers are powered between the +6V and -6V rails with a lot of bypassing. The amplifiers themselves do not require stability compensation, but good circuit layout is necessary for overall stability without VHF parasitic oscillation.

10. Deflection Yoke

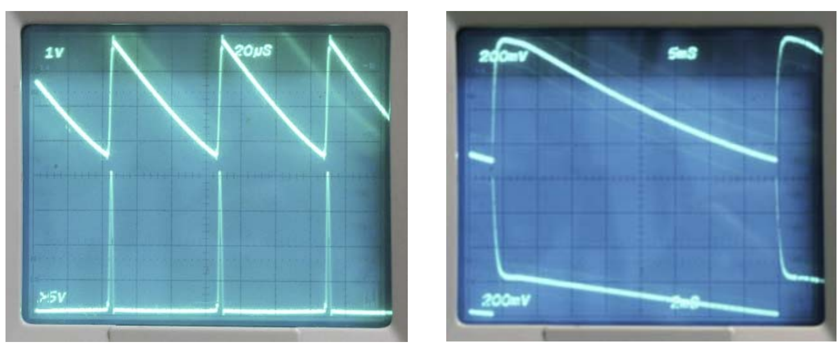
The deflection yoke is of unknown origin and includes a separate set of centering coils that are not presently used. Since it is an unknown, the properties had to be determined. First, the DC resistance and inductance were measured. To determine the magnetization, a small precision-wound search coil was made and each set of deflection coils activated with a known AC current of 500 or 1000 Hz. The field along the axis at many points was measured with the search coil, and the integral magnetization calculated.

Yoke repurposed for the iconoscope.

Knowing the rigidity of a 1 kV electron beam and the deflection angle of ±0.3 radians, the peak current through the coil could be calculated, which is 100-200 mA, depending on the direction of deflection. A circuit simulation determined the voltage waveforms required, which amounted to a 500 volt pulse for the horizontal deflection coil. The vertical coil required a combination of pulse and sawtooth waveform of about 2 volts. Each current waveform is monitored by a 10 ohm resistor in the return lead of each yoke, and the horizontal current waveform was used for the horizontal shading signal.

The horizontal current (top) and voltage are shown on the left, and the vertical on the right.

The deflection coil had to be completely shielded with grounded copper screen to reduce interference with the video signal.

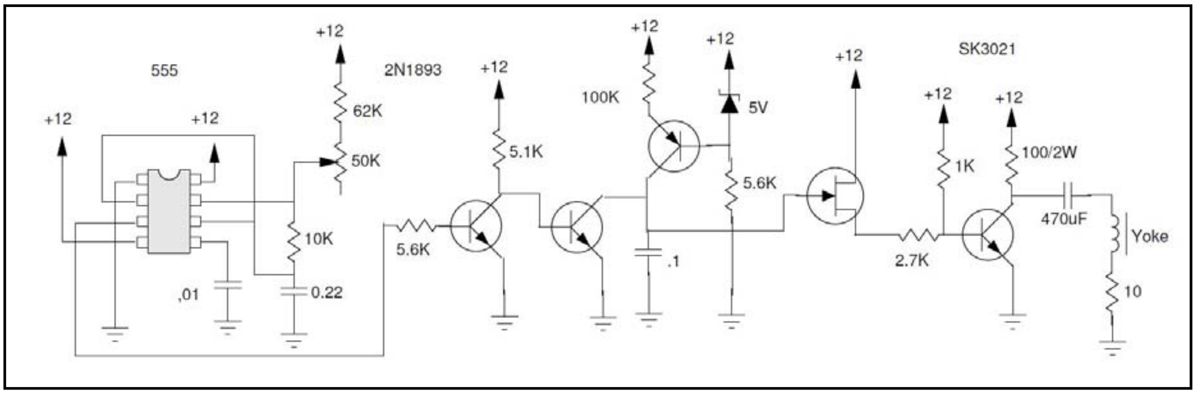


Oscilloscope images: Left is the horizontal sweep; Right is vertical sweep.

11. Vertical Deflection System

The vertical deflection system is straightforward: a 555 timer generates a 60 Hz pulse waveform with a 10% duty factor.

The following inverter applies a positive reset pulse to the discharge NPN transistor. A PNP current source supplies the constant current, producing a linear ramp on the 0.1 uF capacitor that is amplified by the FET-NPN Darlington that drives the horizontal yoke through a DC blocking capacitor. The output transistor is a SK3021 that can take a several hundred volt pulse on the collector, which is set on a heat sink. The only control is the 50K 10-turn screwdriver pot that sets the frequency.



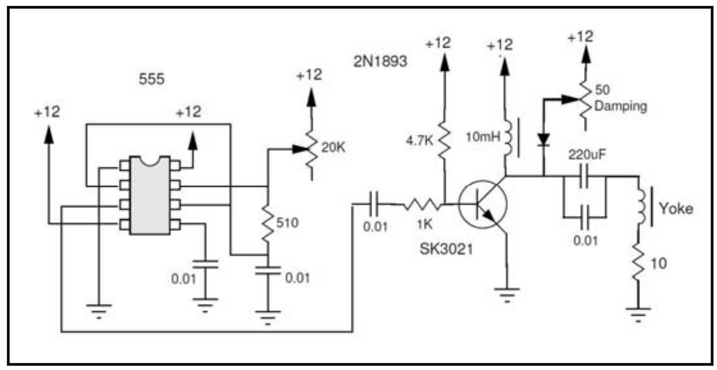
Vertical deflection circuit.

12. Horizontal Deflection System

The horizontal deflection looks simpler, but it is not.

A 555 timer generates a 15750 Hz pulse with a 10% duty factor and applies it directly to the base of the SK3021 output transistor. The transistor is biased on during the cycle, so the magnetic field in the inductor in the collector lead stores magnetic energy.

The transistor is suddenly cut off at the end of the line of sweep, producing a several hundred positive-going voltage pulse that is conducted to the horizontal deflection yoke through the DC block. The yoke presents an inductive load to the driver, so the current waveform is a linear sawtooth.



Horizontal deflection circuit.

The diode and pot in the collector lead controls the overshoot (damping) of the flyback pulse.

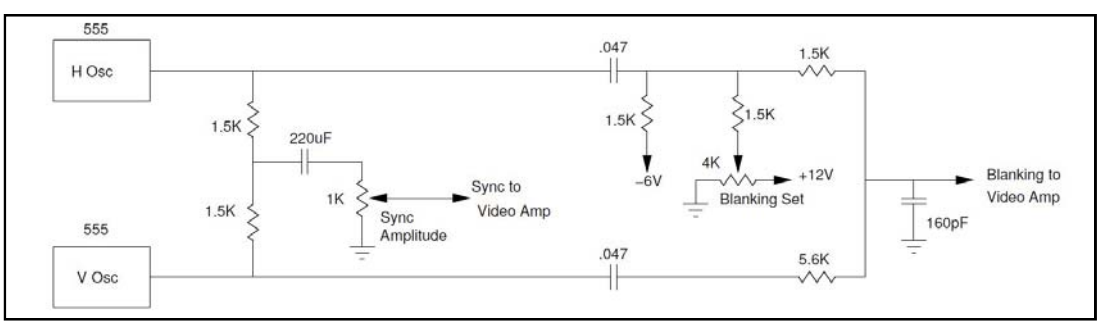
The horizontal linearity is not yet completely satisfactory, and will be worked on in the future. The horizontal sawtooth waveform taken from the 10 ohm resistor in the yoke return leg is used to provide a horizontal shading signal that is fed back to the video amplifier.

13. Synchronism and Blanking Insertion

Both sync and blanking waveforms are required and are derived directly from the pulse waveform from each of the 555 timers.

To generate the sync signal, the two signals are simply added and fed to the video amplifier output stage and the amplitude is controlled by the 1K pot.

The blanking signal is fed to the FET series switch right before the video output stage. The blanking removes a large interference pulse in the video signal during retrace that results from radiation from the deflection yoke, even through



Sync and blanking circuit.

the yoke has been Faraday shielded. The 4K pot sets the DC level of the blanking pulse so that full video comes through outside the blanking period, and no video comes through during blanking. No pedestal is seen on the video signal as a result of the very simple switch configuration.

14. Power Supplies

The LV and HV power supplies are commercial units. The LV power supply is an open-frame unit supplying+12V and -6V. A one-chip TO-3 6 volt regulator supplies the +6V from the +12V supply.

The HV power supply is a regulated commercial supply that sets the output voltage with decade voltage controls with a resolution of 1 volt.

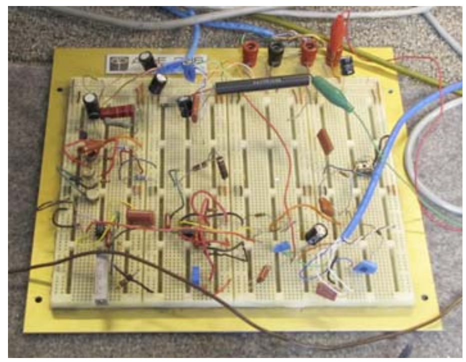
The power is supplied to the modules through various connectors, such as HV coaxial connectors, or DB-9 connector to the camera control unit.

Three octal connectors are provided on the rear of the camera providing connections to the yoke from the CCU and power and signal to the CCU. A third connector provides the high voltages from the HV divider module.

15. Packaging

The deflection and video chain are collected together in the CCU, the Camera Control Unit. During development, the deflection circuits were created on a protoboard.

After a satisfactory design was achieved, the circuits were transferred to a perf board and placed in a cabinet with connectors to the power supplies, to the camera body and to the monitor.



Camera Control Unit prototype.

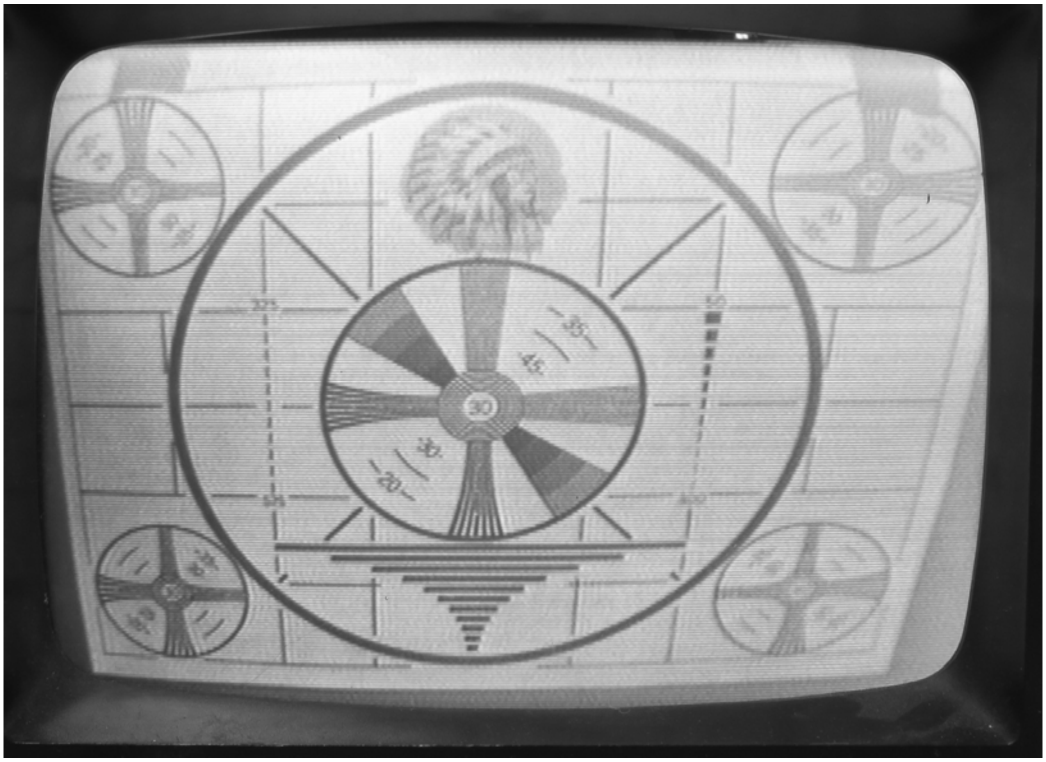
Views of the interior and front and rear panels of the finished Camera Control Unit.

16. Performance

The performance seems to be equal to contemporary descriptions given in the 1930's report as far as image quality and lighting requirements. The 1850A iconoscope appears to be fully operational.

Lighting requirements cited in contemporary accounts indicated that an illumination of 3000 foot-candles was required, typical of outdoor sunlight on a typical spring or fall day. The iconoscope is mainly blue-sensitive, so for indoor lighting with incandescent bulbs, which are blue-poor, a lot of light was required, which was difficult for live talent.

The ultimate resolution of the iconoscope is several hundred lines. With the Indian head test pattern, the resolution seems to be near to commercial quality. Some noise is visible in the picture, which agrees with contemporary accounts of signal-to-noise figures of perhaps 30 dB or so.



Televised camera image of a test pattern.

Camera image taken outdoors.

17. Future Development, Lessons Learned

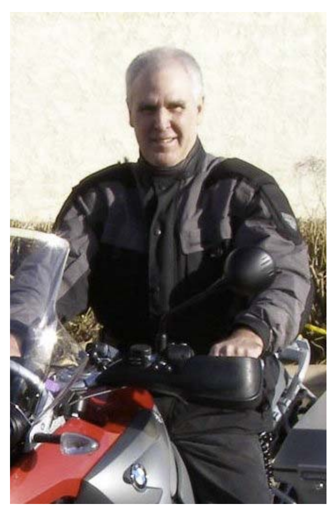
That it works at all is a miracle. The video amplifier chain seems to work well, although during development, some instability issues stemming from the high-gain, wide-bandwidth amplifier chain produced some oscillations in the 50-200 MHz range, which were difficult to diagnose until a wide-band spectrum analyzer was used to find the oscillation.

Complete shielding of the iconoscope and all following amplifiers is essential. RF interference from the broadcast band, as well as lamp ballasts easily sneaks in anywhere. The camera body was designed from the outset to be a Faraday cage, but additional shielding of components inside the camera body was needed.

The deflection circuits are less satisfactory, as the linearity is not ideal, and vertical retrace lines are apparent. These have proven to be difficult to correct so far.

Another test pattern.

The Author



Dr. John Staples, W6BM, designs and builds particle accelerators at the Lawrence Berkeley National Laboratory. He received his Extra Class ham license and First Class Radiotelephone and Radar licenses in 1958. Besides being an avid collector of vintage electronics, he has been a passionate motorcyclist for over 50 years.

All pictures were taken by the author.

◊

Tales of the Pioneers — *Some personal history from the Society of Wireless Pioneers*

By Dick Singer, K6KSG, SoWP member 662

I worked for the CIA

Fig. 1: Dick Singer on the USS Midway in a transmitter room in 1959.

I am an old Morse code CW radio guy. The FCC first licensed me in 1958. I was on contract for the Central Intelligence Agency (CIA) at sea during the raising of the Soviet Submarine *K-129* that had sunk northwest of Hawaii at a depth of 3 miles. Because of the great depth, the sub was considered unsalvageable. Because the sub had nuclear weapons and communications that were of great interest to the CIA, the Glomar Explorer was built by Hughes for the CIA for the express purpose of recovering the sub; Hughes designed it to appear as a drilling platform.

In 1973 I answered an advertisement in the *Los Angeles Times*. The ad was looking for electronics and communications people. It was the Summa Corporation and I went in for an interview. They hired me because I had served in the U.S. Navy. (See figure 1, Dick Singer aboard the USS *Midway* in 1959). Summa sent me to Chester, Pennsylvania to join the Hughes *Glomar Explorer* in the shipyard. That is when I met senior Radioman Tullio D'Angelo. Summa was still building the ship and it was nearly finished. Tullio and I installed all the communications equipment and tested everything to be sure it all worked properly. During that time some people took me to a nearby motel and told me to sign secret papers for the Central Intelligence Agency (CIA). Needless to say I was flabbergasted. From then on it was mum as for what the ship was built for. I stayed with the project until 1975 when they laid her up.

Nearby are some photos of the CIA ship Hughes *Glomar Explorer* (figures 2 & 3, showing antennas) that I worked on 1973 to 1975 when it was decommissioned. Its radio callsign was WCHG. I was on 'A' Crew. This crew picked up the sunken Soviet nuclear-armed submarine *K-129*. Another crew, the 'B' Crew, disposed of the sub after they relieved us in Hawaii. Tullio and I stood 12-hour watches in the radio room. It had to be open 24 hours a day during the mission. (See figure 4, radiomen Singer and D'Angelo aboard the vessel). There were no windows or portholes in the radio room. (See figure 5, the radio equipment). Communications were mostly CW Morse code or radio-teletype (RTTY). All Morse code CW messages were in plain English. (See figure 6, from a CIA video of Dick Singer operating a chrome Vibroplex "bug" key aboard the *Glomar Explorer*).

Fig. 2: Hughes Glomar Explorer, WCHG. Note antennas. The top right antenna on the derrick tower is the MF Beacon antenna for helicopter navigation to the ship.

Fig. 3: Another view of the Glomar Explorer at sunset.

A declassified video titled "AZORIAN The Raising of the *K-129*" tells the story. PBS sells it in their online store and it's on YouTube (see the notes at the end of this article for link).

My Radio History

I qualified for this CIA work as a result of my long involvement in radio. In 1947 my Uncle Parker Ingram was a ham (W3NAP/SK ["silent key" -- deceased]). He worked for the federal government. My family visited him in Baltimore, Maryland. His ham station with all the relay racks really impressed me. He built most of his equipment. I decided that one day I would like to be a ham.

I took electric shop in school at age 15. The teacher Mr. Butcher said if I got a Novice amateur radio license from the F.C.C. he would give me an A for the semester. One of the other students, Walt Shubin (K6LQO now K6WAS) said he was a ham and that he would teach me the code. I would go over to Walt's house and practice every night. I learned the code in 1957 but got my licenses in 1958. I started with a Heathkit AT-1 transmitter and a Hallicrafters S-20-R receiver, and a long wire antenna. I later upgraded to a DX-40 transmitter and a Hammarlund HQ-100 receiver and dipoles for antennas.

In 1959 I enlisted into the Navy. They said: We *will* make a radioman out of you. I was later assigned to the USS *Midway* (CVA-41), callsign NIIW. I had to learn Morse all over again because the Navy operators had to type messages while receiving. I did not know how to type, so I had to learn a Morse sound and associate it with a key top on the typewriter. I did operate CW on the ship but I wiggled my way back into the transmitter room. I was in my element there. (See, *e.g.*, figure 7, Dick Singer at a transmitter rack on the Hughes *Glomar Explorer*).

When I served on the *Midway*, the Navy staged proficiency tests: the Naval station in Hawaii would send us a change in frequency. I would set up the new frequency on the AN/SRT long distance 500- watt transmitter. We got the Navy 'E' for excellence because we beat the Naval station back on the air each time, all on CW.

After the Navy I bounced around with different jobs. I worked at a rock and sand plant and worked part time in a TV shop repairing TVs and the suddenly popular Citizen Band 27 MHz transceiver CBs. I decided to try for my commercial telegraph license and obtained it in 1968. I still have my First Class Radiotelegraph commercial license as well the ICET Electronic Technician certificate from the Institute for the Certification of Engineering Technicians.

I joined the Society of Wireless Pioneers in 1968, in the latter part of the year, while still living in California. In 1969 or 1970 I dropped in at coastal radio station KOK. ITT (International Telephone and Telegraph, abbreviated ITT) operated radio KOK as a coastal station in Los Angeles. I was going to break in as an operator. It was a real experience keying all that power on 500 KHz MF (medium frequencies), and the HF (high frequencies) band of frequencies. I loved it.

Fig. 4: Hughes Glomar Explorer, WCHG. Dick Singer, K6KSG and partner Tullio D'Angelo standing, 1973.

Fig. 5: Hughes Glomar Explorer WCHG transmitters: Collins 208U-3 (3 KW), and Communications Associates Inc. Transceiver (1 KW).

Fig. 6: Screen capture of Dick Singer operating his chrome bug aboard the Hughes Glomar Explorer, from a CIA video.

Fig. 7: Dick Singer sitting at a transmitter rack on the Hughes Glomar Explorer.

Radio Officer on the High Seas

I later shipped out as Radio Officer ("R/O") on a steam tramp tanker SS *Mount - Explorer* (callsign KTSY) in 1976 bound for Egypt. (See figure 8, its radio room). The Captain had a heart attack and I made schedules with Medical-Rome on CW for medical advice. (The International Radio Medical Centre (C.I.R.M.) provides free medical assistance to seafarers of any nationality worldwide).

We later came back to the states and loaded for Russia, a place called Novorossiysk (a port in the Black Sea) next to Georgia. The ship had a World War Two era ITT 4U radiotelegraph rack. I worked WCC (Cape Cod; RCA Chatam) from the states all the way to Novorossiysk. When in the Black Sea I would only have a window of one and a half hours on high frequency (HF) to receive and send my message traffic ("QTC"). Then we lost long distance radio propagation. I set it as a challenge for myself to stay with WCC for the voyage. It was great to accomplish the effort. I stayed on the tanker for six months and was then, when relieved, I took a vacation.

In September 1976 I had in an application for Exxon Shipping Company. They had called while I was on the tramp tanker and my wife told me when I returned home. I waited for a week before calling them in Houston. I didn't want to go back to sea for a while, but they hired me over the phone and off I went again. I signed on as Radio Electronics Officer and stayed with them for 18 years until I retired.

Fig. 8: ITT Telegraph rack on the SS Mount Explorer, KTSY, in 1976.

Exxon sent me to several schools, the Fort Schuyler Maritime Academy at Bronx, N.Y. for instrumentation and automation, and Sperry Marine for the Collision Avoidance systems. Later I attended the Communications Associates, Inc. single sideband school, then the Raytheon radar school, and also learned about Limitorque electrical valve systems, and the Tano engine room console. The SS *Exxon New Orleans* was my favorite ship. (See figure 9, Dick Singer copying KPH). All in all, I served on 19 ships in my 22-year career as a seagoing Radio Electronics Officer. I retired from Exxon Oil Company in 1994. It has been sad to since hear the demise of CW on the marine frequencies.

The Society of Wireless Pioneers

The Society of Wireless Pioneers conducted Morse code CW nets in the 40 and 80-meter ham bands. I would check in once in a while when I was still sailing. Bob Shrader (W6BOB/SK; he wrote a well respected book on radio operations) controlled the SoWP net on 80 meters up until several years ago. He was always an excellent operator. Bob kept after me to take the net on 80 meters several years ago, which I did. (See figure 12, Dick Singer at his ham station K6KSG). Over the years Ben Russell, N6SL/SK, took the 40-meter net and stayed with it many years. Due to Ben's health I manned the nets on 20 meters and 40 meters. We dropped the 80-meter net due to heavy noise on the bands during our net times. However we operate on Thursdays at 0900 Eastern Time on 14055 KHz and again on 7052 KHz at 2200 Eastern Time. I am net control. We don't have many folks left for so many now are Silent Keys. We normally have around five or six stations who check in. We are trying to keep the nets going. All radio amateurs are welcome to join in.

Fig. 9: Exxon New Orleans, WNDM. Dick Singer copying KPH (Bolinas, CA) at the ITT 4U Telegraph rack, 1979.

Restoring My Vibroplex Radio-Telegraph Key

The Vibroplex telegraph key pictured nearby is my latest project. This key has been in my possession for many years. In 1957 I bought this key from J.J. Glass in Los Angeles a World War Two "War Surplus" store. I paid five dollars for it. I didn't know how to use it but I just had to have it. It has been on all the Merchant Ships I sailed on and used it to pass many telegraph messages. I still use it on Morse (CW) for my CW nets on ham radio. It was getting to be in pretty sorry shape after all these years. So I removed everything down to the base of the unit. I wire-wheeled it to remove all the paint down to bare metal. Ooops! I found out it was a powder coated finish and I made a mess out of it. So decided to just polish up all the brass fittings and put it back together so I can use it on the nets. The nets (including the Society of Wireless Pioneers net) are mostly old commercial CW operators and we get together on CW once a week. The only thing is, the guys are all dying off.

You can read the information on the photos (see figures 10 & 11) — the contract with Vibroplex issued in 1942 for War production. (Vibroplex made it in Brooklyn, NY). It is a great key and I wonder how many coded messages were sent during World War Two with it. I have it completed except I need to insert a brass washer in the thumb side of the lever. This will take the slack out of it and help align the lever. I will wait until the weather warms up then I will take it apart again and paint the base black crinkle paint.

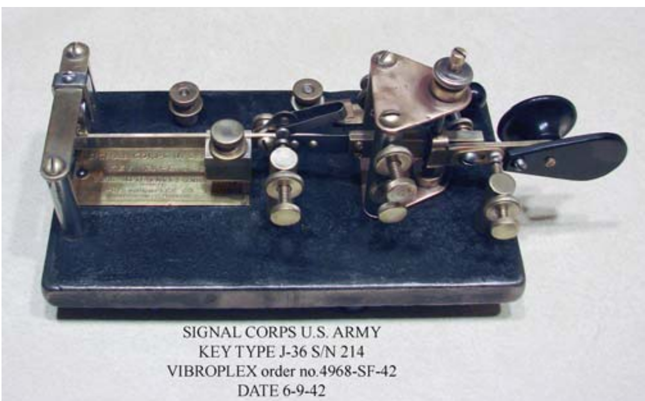


Fig.10: 1942 Vibroplex restored.

Fig.11: Another view showing data plate detail.

73 de Dick Singer, K6KSG, SoWP 662, to all the R/Os that I have passed on ships in the middle of the night on the high seas, and to CHRS for preserving the Society of Wireless Pioneers archives.

Fig. 12: Dick Singer today at his ham station K6KSG working with a DX-40 and HR-60 wearing a Maritime Radio Historical Society outfit.

Article edited by Bart Lee.

Notes:

- Dick Singer has also posted on: www.trafficlist.net/radio-officer/richard-dick-singer/
- For the raising of the Soviet submarine *K-129* see: https://www.youtube.com/watch?v=jDqCb_83Xcg
- See also: https://en.wikipedia.org/wiki/Soviet_submarine_K-129_(1960)

◊

Lev Termin — Radio Engineering, the Theremin, and Espionage

By Richard Watts

Lev Sergeyevich Termin was a gifted scientist and inventor with wide interests who lived through and navigated tense and complex world events. During the 1920s and 1930s he was a radio engineer and prodigious inventor. He used radio technologies such as heterodyning to invent devices that operated spatially at a distance as in the Theremin musical instrument and sentry alarms. For a brief time in the 1920s his mechanical television design was the most advanced. He was a prolific inventor who devised numerous other electronic innovations. The primary source for this article and unattributed photos is the book *Theremin — Ether Music and Espionage* by Albert Glinsky.

Lev Termin

In 1896, Lev Termin was born in St. Petersburg, Russia and raised in a comfortable, close -nit and supportive home with his parents, grandmother, and younger sister in late-Tsarist Russia. From an early age, Lev was exceptionally inquisitive. His parents played piano much to the interest of Lev. When Lev was a young child, he urged his parents gave him lessons but he became impatient with the repetition to develop the conditioned muscular training needed to be proficient. He later said "I realized there was a gap between music itself and its mechanical production, and I wanted to unite both of them."

He demonstrated exceptional ability and, in his early teens, demonstrated an aptitude for physics. His teacher invited him to do independent electrical research in the gymnasium physics lab wherein he did experiments with high-frequency currents, optical devices, and magnetic fields. He also studied astronomy and constructed an observatory in the garden of his home. He investigated all the known star and, at fifteen, reported to the Astronomical Society of a star he discovered. He also continued musical studies. In 1914, Lev graduated from the gymnasium with honors and entered Petrograd University (St. Petersburg had been renamed to Petrograd). Lev continued to impress and was allowed to have his own room for independent research – unheard of for a second-year student.

On August 1st, the First World War erupted when Germany declared war on Russia. Fifteen million Russians were drafted. Lev received a draft call in early 1916, but, because of his advanced electrical knowledge, his deans maneuvered him into the Nicolayeveska Military Engineering School in Petrograd for a six-month engineering course. Lev was disappointed as this would divert him from physics research, but understood the practical importance that engineering experience would provide; plus this kept him from the dangers of the front lines. He went to the Graduate Electrotechnical School majoring in radio engineering. After graduation in 1916, he soon oversaw the construction of a powerful radio transmitting station to enable the war front at Saratov to communicate with Moscow over 400 miles away.

WWI had created much hardship fanning a growing movement of discontent between the masses and Tsarist Romanov rule. In October 1917, the Bolshevik party led a revolt that unseated local and regional governments and ended the Tsarist rule with Lenin becoming the new head of the Soviet government, and the seat of power moved from Petrograd to Moscow. By now, Lev had earned a reputation as an expert in radio technology and engineering. Lev was reassigned to Moscow to serve as deputy chief to the new Red Army's Military Radiotechnical Laboratory. He was a Bolshevik now and decisions regarding his immediate future were made for him with no exits or alternatives.

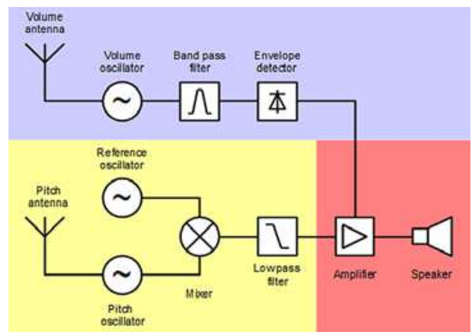
In 1919, Lev was assigned to Petrograd, where fighting was active, as Chief of the Transmitter for the most powerful radio station in Russia. When the station was about to be overrun by resistance forces, Lev was forced to transport the transmitters on rail cars to safety in the Ural Mountains and demolish the transmit towers. Lev remained in Petrograd and, after a short time, was able to accept an offer to be supervisor of a high-frequency oscillations laboratory at the Physico-Technical Institute. Lev welcomed the opportunity and relative sanctuary.

Lev kept pace with radio engineering advancements from De Forest, Armstrong, et al, including improvements in the Audion tube. He was intrigued by the notion that the human body exhibited capacitive properties that could influence nearby electrical circuits. From this, he devised a simple burglar alarm that would set off a signal if a person were near enough for their capacitance to be detected. In its design, Lev used an oscillating audion as a mini transmitter connected to a small antenna. It was adjusted so the presence of a person within the radiating field of 15 feet or so would affect the capacity of the circuit and alter the oscillating frequency, in turn causing a switch to close and an alarm to sound. He called it the Radio Watchman.

Lev was then asked to design a device to measure the density and dielectric constant of gases under varying pressure and temperature. He assembled a circuit and placed a gas between two plates of a capacitor; he found that a change in temperature resulted in the expansion of the gas and changed the circuit's capacity. Further, he utilized an audion oscillator in a tuned circuit similar to the Radio Watchman, and was able to "tune in" the density of a particular gas. The slightest drift in properties of the gas changed the capacity of the circuit and the pitch of a whistling note. He noticed that the device was so sensitive, it also responded to his hand movements.

Driven from his affinity toward music, he began experimenting to generate musical tones with human capacity. He developed a spatially-controlled musical instrument based on heterodyning principals from radio engineering. He called this instrument the Etherphone (later renamed as the Theremin). Lev demonstrated it to his supervisor, Ioffe, in October 1920 and a month later gave his first lecture and concert to students at the institute; coincidentally occurred at the same time radio station, KDKA in Pittsburg debuted. In 1921, he filed for a Russian patent for the Etherphone.

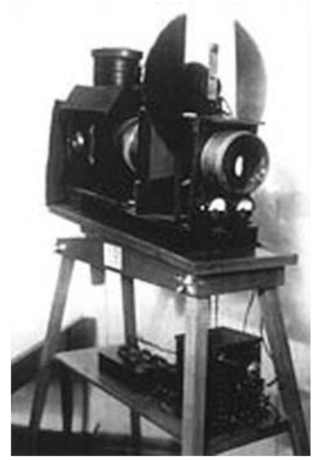
The original design of the Etherphone employed two high-frequency oscillators for control of the pitch of the instrument. Both pitch oscillators were tuned to at the same frequency at about 172 kHz. The frequency of the pitch reference oscillator was fixed while the other was made variable. The tuned circuit of the variable oscillator was connected to a vertical antenna mounted to the outside of the cabinet which radiated a weak electromagnetic field and served as one plane of a capacitor. A nearby human hand with its natural body capacitance served as the other plane of the capacitor. As the hand moved closer to the antenna, capacitance increased reducing the frequency of the variable oscillator. The frequency produced by both the fixed and variable oscillators are mixed together, i.e. heterodyned, producing a signal that is the sum and difference of the two frequencies. The Theremin used the "difference" frequency to produce an audible tone. For example, if the hand caused the variable frequency to be lowered to 171,700.26 Hz , the difference from the 172 kHz fixed oscillator would be 299.74 Hz which is middle C on the music scale. When no hand is near, the fixed and variable oscillators produce the same frequency having no difference, and when heterodyned together, produce a no audible tone or a "zero beat." This instrument could produce three to four octaves. To play a song, the right hand is moved at specific distances from the antenna to produce musical notes forming a melody. Subtle hand techniques can also alter the character of a note. For example, the hand can be subtly wavered or vibrated producing vibrato.



Theremin block diagram. Wikipedia

Etherphone with a foot volume control and mute control button played by Julius Goldberg circa 1927.

To control volume, Lev first experimented with a foot pedal. He also added a control button to mute the sound when the hand is moved from one note to another. Then, to make playing the instrument more fluid, he evolved the design replacing the foot pedal and button with a third oscillator circuit to control volume. It also resonated at high frequency (about 420 kHz) which is in a different range from the pitch oscillators to avoid interaction. The volume oscillator was connected to a second curved antenna that protruded from the left side of the cabinet. The left hand when near this antenna changed the capacitance and the frequency of this oscillator which was detected. When operating at resonance with the hand away from the antenna, the detected voltage controlled the filament voltage to audio amplifier to produce maximum gain. Conversely, moving the left hand near the antenna lowered the oscillator frequency reducing the detected voltage, in turn lowering the filament voltage of the audio amplifier reducing its gain and thus the volume.



An Illumovox about 1928.

As Lev pursued various radio science, astronomy, and physics projects at the institute, he took advantage of any opportunity to give concerts and demonstrations of his Etherphone primarily at technological forums. At one such conference with noted scientists, Lev was invited to do a demonstration for Lenin – a very great honor. In March 1922 Lev demonstrated the Radio Watchman and the Etherphone to Lenin who was very engaged and impressed. A high priority was to implement electrification throughout Russia and Lenin saw both the inventions useful as propaganda tools to generate public acceptance. Lev had made quite an impression on Lenin. He immediately began touring Russia giving demonstrations to promote electrification.

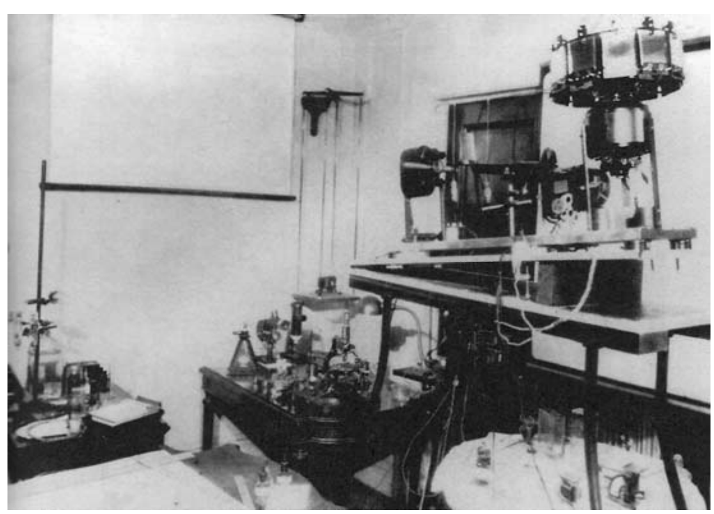
Lev continued to improve the design and to make updates as vacuum tubes evolved. He devised a rotating color wheel, which he called an Illumovox, that connected to the Etherphone and projected color hues that corresponded to the Etherphone pitch being played. In 1924 when loudspeakers became available, he was able to produce more volume and could play in larger venues to bigger audiences. His concerts drew huge crowds and Lev's reputation grew, the press redubbed the Etherphone as a Terminvox, i.e. Theremin's voice.

Katia Constantinova circa 1924, Lev's first wife.

In 1924 Lenin died and Stalin assumed power. St. Petersburg which had been rechristened Petrograd was now renamed Leningrad. And in 1924, Lev married Katia Pavlovna Constantinova.

At that time, the Radio Watchman was seen as an effective security device for banks and government institutions. Installing these systems consumed much of his time, which was a distraction from doing research, but important to the institute in staying relevant to the new regime.

Lev's wide interests included Vision at a Distance (early television). He had been following developments including pre-WWI efforts by Russian scientists including V. K. Zworykin. At the institute in his spare time, he designed an experimental camera that used a mirror sweep, which was a rotating disk with mirrors that reflected light from an image onto a photocell. The receiver used another mirror sweep to project the image onto a screen. His system was able to produce a 16-line image. At the time, other devices utilizing different mechanical approaches (primarily the Nipkow disk) were being demonstrated by John Baird in England and Charles Jenkins in the United States. Over the next two years, Lev improved his mirror sweep system improving resolution to 32 lines, then 64 lines. In 1925, he demonstrated scanning a person and wirelessly transmitting it to the next room where a very recognizable image was received and projected on a five foot square screen.



Television system circa 1926 developed by Lev Termin.

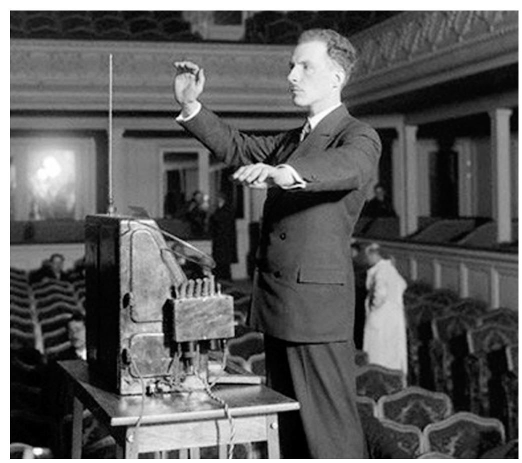
By 1926, he developed a new 100-line system, which was a record at the time; the received image offered clear recognition of a face even when the person was moving. The camera could be used in normal daylight, without the additional intense lighting required in competing systems. In a demonstration for Stalin, the camera was set up outside and tracked passers-by at a distance up to 160 feet away unmatched by any competing technologies of the day. Stalin was so impressed, he directed that the system be implemented as an electronic sentinel for border troops. Lev's Vision at a Distance system was immediately made top secret; all writings were made secret and no technical details of this system were ever disclosed – and, for the foreseeable future, Lev was powerless to develop his system any further. For his efforts, the government rewarded Lev with a coupon for a "big food parcel."


Termin with his keyboard harmonium, 1927.

In 1926, Lev developed an electronic keyboard resembling a miniature upright piano that he called the Electric Harmonium. It had 49 keys and a 4-octave range. On the vertical surface rising from the back of the keyboard, 27 rotary condenser dials provide adjustment of pitch fluctuations of up to 1/100 of a tone on each note. Like a piano, it was polymorphic (capable of producing multiple notes simultaneously). He had apparently only used it for acoustic research and never in performance.

The Stalin regime envisioned socialist dominance in the world. In Machiavellian fashion, they set their sights on Germany as it was weak and its social order disrupted from the impact of WWI. The Soviets initiated clandestine efforts to create social unrest and support for socialism, and also used Germany as cloak for their espionage apparatus. M. J. Goldberg & Sons was created as a medical equipment company but served as a front for industrial espionage. A tactic was to patent Russian technology in Germany which then could be offered under license to Western countries; these countries, including the United States, avoided doing business with Russia but were willing to engage with Germany. The proceeds from licensing along any information about Western technologies would circuitously wind its way into Russia to primarily fund and serve espionage programs. Lev's supervisor, Ioffe, had been assigned by Soviet intelligence to create German patent agreements for technologies associated with the institute that included Lev's Radio Watchman, Terminvox, plus an airplane altimeter Lev had just invented. Ioffe periodically summoned Lev to Germany to assist in transferring technologies.

In 1927, Lev was directed by Soviet intelligence to go on extended "business trips" to learn about new foreign technologies. To do this, Lev set out as a cultural ambassador demonstrating his Terminvox in foreign countries and to create interest in licensing and manufacturing his devices. He spoke enough French and German that he could move easily and blended in new surroundings. Lev's wife, Katia was compelled by the government to remain in Leningrad to insure that Lev wouldn't bolt in a moment of weakness (she would later be allowed to join him in Paris, then the U.S.).


Theremin preparing for a PARIS concert, 1927.

He first performed concerts throughout Germany to spellbound audiences and to luminaries such as Albert Einstein, tenor Leo Slezak, and Nobel laureate Gerhart Hauptman. In Germany Lev adopted the Gallic origin of his name, Leon Theremin. Sensing something major, European, Great Britain, and U.S. press provided wide coverage. The media began referring to it as "ether music" and "ether waves." The New York Times reported that "good musicians learned to play them in fortnight." As word spread, tourists from Europe and elsewhere came to witness the wonder. Lev (now Leon) was on a roll. Some critics felt the music did not compare to traditional instruments, but had little effect on audience acceptance. In late 1927 he performed in Paris and London, and in December 1927, Theremin arrived in New York to perform. He learned it was advantageous to precede a public concert with a private reception for noted and influential guests. He spent nine months touring cities such as Washington D.C., Chicago, Akron, Cleveland, Detroit, Philadelphia. In July 1928, Katia was able to join him.

In 1929, the RCA was sufficiently impressed that they entered into a two-year licensing contract with Goldman & Sons to pay $100,000 for exclusive patent rights in the U.S. for the Thereminvox, Radio Watchman, and the altimeter; Further, they agreed to pay an annual 5% royalty, with a minimum guarantee of $25,000 with or without sales. At the end of two years, RCA had an option to continue this arrangement or purchase the U.S. patent rights for $500,000.

By this time Leon was able to promote his television system. David Sarnoff, president of RCA, saw the importance of television in maintaining future market dominance. Even though RCA was committed to an all electronic design utilizing cathode ray tube technology, Mr. Sarnoff kept his options open and squelched competition by purchasing the rights to competing technologies. Hence, RCA bought an option from Leon Theremin for $20,000 for exclusive U.S. rights to a television prototype. Later in 1930, RCA offered to release the rights back to Theremin for $20,000, however, Leon didn't accept the offer nor did he pursue any further television research since his system was no longer competitive.

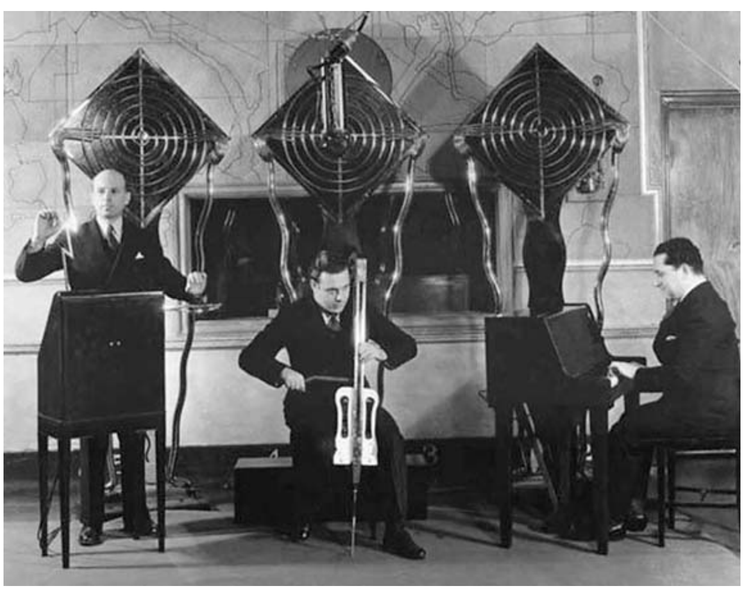
RCA Theremin paired with an RCA model 106 speaker. RadiolaGuy.com

Westinghouse and General Electric manufactured the Theremin for RCA. The instrument was designed by a team from the three companies. Leon consulted with RCA during preliminary planning and later to oversee and approve every step in the design process. RCA initially built only 500 units. Production costs were estimated at $90 per unit and initially was to sell for $129.95; However, when introduced, the actual price was $175 not including tubes or speaker. The total cost including tubes and an RCA model 106 speaker was about $232 which is equivalent to about $3,750 today. What was originally envisioned as affordable by the average household, was now very much a luxury item.

An RCA Theremin played by Alexandra Stepanoff on NBC.

In September, 1929, RCA announced the Theremin, marketing it as an "absolutely unique instrument that anyone without musical knowledge can play." It was debuted at the New York World's Fair and broadcast live over the WJZ radio network. In early October, the 500 units were manufactured and RCA Sales distributed them to New York (300), Chicago (135), Atlanta (30), Dallas (10), and San Francisco (25). That same month on October 29, 1929, the stock market crashed.

The Theremin was promoted in concerts and vaudeville performances, on the NBC radio network, and local promotional events by dealers. Much of the advertising was left to the individual dealers, however, many did not understand the principles of the instrument or how to promote it. Despite their efforts and even though there was much public curiosity and fascination, sales for the instrument were very slow. By 1932, RCA did sell the 500 units but did not make anymore, nor did they renew their license when the two-year license contract expired. RCA sold the last Theremin in 1932. Today, the Theremin is a very rare instrument; currently only 114 are known to exist and are documented in an online registry at http://rcatheremin.com/registry.php .



1932 Radio performance with a Theremin (left), Electric Fingerboard i.e. Cello (center), and a keyboard Theremin (right). Three tall speakers are behind.

There were a few legitimate competitors. The most notable was, Maurice Martenot of France, who in 1928 developed the Ondes Martenot using a similar heterodyne design. It differed from the Theremin in that, instead of an antenna operated by the spatial relationship of a nearby hand, a string was tugged back and forth horizontally by the right forefinger; the string ran over a pulley controlling the variable pitch oscillator frequency. Early models had a dummy keyboard over which the hand could move that gave the user an indication of the note being played. Later models had a standard keyboard and were capable of 5 to 7 octaves. The left hand could control a button for articulation and a knob for volume. The Ondes Martenot still has a following and is still used in orchestral performances today.

Lev's early musical training centered around the Cello. So it is natural that, in 1922, he developed an electronic instrument loosely resembling a cello that he called the Electric Fingerboard Theremin. In 1929, a later model was used experimentally by Leopold Stokowski, conductor of the Philadelphia Orchestra, in concerts to reinforce bass lines. The instrument was held like a cello between the player's knees. It had a black cylindrical rod about 4" wide, about the width of a cello fingerboard upon which a celluloid fingerboard was mounted. A lever jutted out from the right that resembled a bow that was used to adjust volume. When played, an electromagnetic field was created along the fingerboard and the player would finger the strip with his or her left hand to determine the pitch much like a cello — a higher finger position on the rod produced a lower pitch, and vice versa. The right hand operated the volume lever.

Clara Rockmore,1934.

1929 and 1930, Leon made and spent many small fortunes including the $25,000 from RCA. In late 1930, with sales of the instrument faltering and RCA's support waning, Leon sought other sources of funds. He formed a business, the "Theremin Studio," financing it with $12,000 in personal loans guaranteed mainly by worthless shares of stock and a promise of interest from the sale of future inventions.

Composer Joseph Schillinger with a Rhythmicon circa1932.

At the studio, Leon gave private lessons. He had been giving private lessons in the U.S. since 1928; his first student was Alexandra Stepanoff who went on to perform with Leon in concerts and promotional events. One of Leon's most notable protégés was Clara Reisenberg (later Rockmore) who was a classically trained violinist. She had a fascination with the Theremin since she first saw it in 1928 and by 1932 was committed to mastering the Theremin. During the 1930s and 1940s, she earned a reputation as a gifted Theremin artist; she was extreme precise and developed exceptional technique that truly impressed critics. Leon also had cultivated devoted patrons. Most notable was Lucie Rosen who became an accomplished Theremin enthusiast, supporter, and close friend. She gave him access into high society and her very wealthy husband on occasion would assist him financially.

Leon continued to develop other instruments. In 1932 from an initial conception plus some funding by composer Henry Cowell, he developed the Rhythmicon, a tool for "scientific, physical, and psychological experiments with rhythm" and is considered by some to be the first drum machine. Each of its sixteen keys sounded its own specific rhythm according to the pitch selected on the pitch wheel. The lowest pitch, or fundamental, sounded one note per beat. The next key sounded the second harmonic providing two beats, and so on up to the sixteenth key that sounded the sixteenth harmonic and sixteen divisions to the beat. The instrument is polymorphic , that is, capable of simultaneously playing multiple rhythms in response to multiple keys be pressed.

Clara Rockmore demonstrating the Terpsitone, 1932.

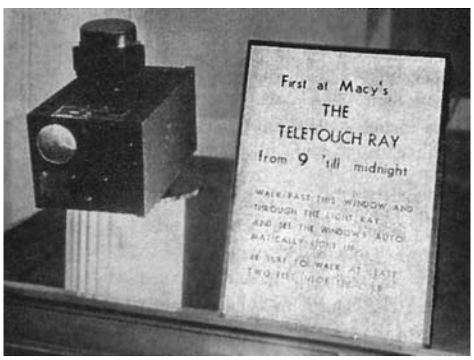
And in 1932 Leon invented the Terpsitone ether wave dance stage which was a Theremin in the large. It was a small stage upon which a dancer's full-body movements controlled the pitch. An insulated plate just beneath the dance platform served as the pitch antenna registering the swooping and rising movements of the dancer. Volume was controlled by an operator off stage. In a later model, Leon added a "visual note indicator" as a guide for the dancer. There were colored lights that responded to the pitch. The Terpsitone was unveiled in April 1932 at Carnegie Hall with Clara Reisenberg performing.

At this April 1932 Carnegie Hall event, Leon also presented the Theremin Electrical Symphony Orchestra that was comprised of sixteen performers playing instruments including Theremins, a Rhythmicon, the Terpsitone, and the Cello-like Electric Fingerboards. In some ways, this was his last hurrah in electronic music as the novelty had worn off, audiences were becoming more blasé, and reviewers were showing less interest and becoming more critical. Theremin was never able to realize his ambition to have an electric ensemble to rival the qualities of an acoustic orchestra. It would be decades later that this goal could be realized by much more sophisticated technology.

Lucie Rosen showing her custom Theremin to bandleader Elliot Laurence.

For the rest of the 1930s, Leon made only a few custom Theremins for close friends and supporters like Clara Rockmore and Lucie Rosen; Enhancements extended the range to seven octaves and provided more timber adjustment. Later in the 1930s, simpler Theremin designs were appearing from competitors, and Theremin plans were published in hobby magazines. For example, Radio-Craft offered an article in 1935.

Leon's marriage to Katia had become distant. Since her arrival to the U.S. in 1928, she was a Lab Technician at a Tuberculosis hospital in New Jersey and didn't participate in Leon's endeavors. In 1932, Leon and Clara had become very close socially and, at one point, Leon proposed marriage. Clara however, had other ideas and accepted a proposal from Robert Rockmore, a lawyer. Their marriage devastated Leon. In 1934 Katia and Leon were officially divorced by a certificate from the Soviet Consulate.



Teletouch Ray advertised in a Macy's window, 1937.

Leon developed a store-window advertising system comprised of turntables, lighting, and sound effects that responded to the movement of an onlooker when they disturbed an electromagnetic field. The system was named Teletouch, or literally "distance touch." In 1933, Leon and associates formed the Teletouch Corp. which offered the advertising display devices plus burglar alarms and gun detection devices. In 1934, the Bureau of Prisons awarded Teletouch a contract for gun-detecting devices to be used at Alcatraz. The device operated successfully then later developed problems with overheating coils resulting in The Bureau of Prisons filing a judgement against Teletouch.

In 1936, Theremin designed security devices utilizing a light source and phototube detector that he called the Teletouch Ray. His design positioned the light source and the photo tube next to each other in the same unit. The light source would illuminate outward and the photocell would detect variations in light reflected from an object like a person. This differed from electric eye devices as the light source and photo cell are positioned some distance apart and pointed at each other; disruption of the beam by someone passing through sets off the device. The electric eye could be easily defeated by shining a substitute light at the eye when passing through; the Teletouch Ray did have this vulnerability. Theremin used the Teletouch Ray to develop a Baby Monitor and an improved store window display control. The latter was used by Macy's and Gimbel's to turn on window display animations and lighting only when an observer was present.

Lavinia Williams, second wife of Leon Theremin.

About that time, dancers of the American Negro Ballet went to Leon's studio where their choreographer arranged for them to try out the Terpsitone dance floor. One of the dancers, Lavinia Williams, made a big impression on Leon. She spoke six languages, painted, danced, and was a voracious reader. She and Leon dated and eventually fell in love. Many of Leon's acquaintances were not comfortable with the inter-racial relationship and distanced themselves; Leon also found he was no longer warmly welcomed in social circles. In spite of the difficulties and with permission from the Soviet government, early in 1938 Lavinia and Leon were secretly married.

Leon was in trouble financially. In 1938, The Teletouch Corporation was marginally viable and was on the verge of failure. It had limited sales accompanied by significant debt. Leon and associates were unable to raise any more capital, so they filed a certificate for another company, Teletouch Industries, Inc. to provide legal shelter and enable them to continue doing business. Leon was also personally deeply in debt and in arrears to the IRS.

Leon had other difficulties as well. He had been in the U.S. on a six-month temporary visa which was repeatedly extended for nine years. In 1934 the FBI had red-flagged him due to over-staying his visa but nothing came of it then. It was clear to him that this would not continue indefinitely. Leon had no desire to relinquish his Russian citizenship to stay in the U.S. so Leon considered returning to Russia. Leon understood that returning to Russia was not without risk. The Soviet regime had a reputation of dire treatment of returning citizens including executions. However, he felt he would be alright since he had been loyal and he was certain he could return to the institute in Leningrad and simply continue his research. So Leon decided to return, a decision he kept secret — even from Lavinia. Leon only told the Lucie Rosen for which he did one last customized Theremin in exchange for her husband paying his travel expenses.

While Leon was in the U.S., he was given ongoing "additional assignments" from Soviet intelligence to gather information about U.S. technology. Their requests seemingly "dealt with seemingly unimportant issues for military purposes." He was more often reported on the technology he had recently created. In the 1930s, the U.S. was lax toward Russians immigration and did not give much importance to the possibly of espionage. With rising tensions with the Germans and Japanese, the U.S. wanted to keep Russia as an ally.

Both Leon and the Soviets wanted his exit to be secret, so he arranged with Soviet intelligence to transport him on a freighter in the same manner espionage agents traveled. On September 23, 1938, Leon left New York bound for Russia. He wanted to take Lavinia, but her papers were refused because this was a secret trip; he was assured that she would follow in two weeks. Lavinia still didn't know he had left — and Lavinia would never be allowed to join him.

In 1927, Lev Theremin, left Russia as a celebrity. Upon his return, he was now Lev Sergeyevich (no longer Leon Theremin or Lev Termin), and there was no one to greet him. He found a country that was impersonal, suspicious, paranoid, and in fear from the ruthless and capricious terror, purges, and massive arrest quotas that had been imposed by the Stalin regime to attain absolute power with zero opposition. At the institute, Ioffe, his old supervisor, met him with detachment and did not have a position for him. Within a month, Lev was broke and could not find work.

In March 1938, he was required to interview with a high Soviet official who received him coldly. Shortly after he was arrested and all his property was confiscated including equipment brought from the U.S. He was transported to Butyrka Prison. There he was interrogated day and night continuously, sleep deprived, and made to stand at attention for extended periods. At the conclusion he was charged as a fascist and a spy for foreign secret services and in August was falsely charged and sentenced to eight years at a Kolyma work camp in Eastern Russia and one of the coldest inhabited places on Earth. In December he was moved again. Russia had a serious shortage of scientists due primarily to the massive deadly purges that included many of the most talented and senior scientists. Lev was given civilian cloths and transferred to Moscow to be confined at the Central State Aero-Hydrodynamics Institute. There he received respectful treatment and was assigned to do aircraft design for which he was poorly qualified but able to contribute.

By 1945, he was designing espionage listening devices. One was a listening device hidden inside a large wooden plaque of the Great Seal of the United States. A delegation of Boy Scouts presented the plaque to U.S. Ambassador Averell Harriman which he hung prominently in his office in the U.S. Embassy in Moscow. The bug was a passive resonate cavity microphone requiring no external power or batteries; since it was passive, it was not detectable by security scanning equipment. The device only activated when and external microwave beam (most probably) at 330 MHz was directed at the antenna from a nearby location outside the embassy causing a medal plate inside a cylinder to resonate as a tuned circuit. Tiny holes near the beak channeled sound waves to the microphone vibrating the diaphragm at one end of the cavity which increased or decreased the volume of the cavity according to the vibrations. The resulting AM modulated signal, which was tuned to a harmonic of the incoming signal, was transmitted via the small antenna. Lev was careful to select a frequency that was not monitored by U.S. intelligence. The device in the plaque was not discovered until 1952. Later, in 1960 when Russia captured U-2 pilot Gary Powers, the U.S. revealed the plaque in a U.N Security Council meeting to offset Soviet arguments and highlight the activity of Soviet intelligence .

Replica of the Great Seal in which the listening device was imbedded.
Cryptomuseum.com

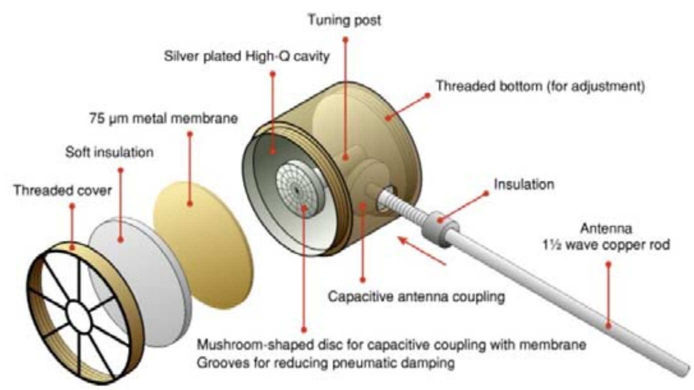


Diagram showing the design of the Great Seal listening device.
Cryptomuseum.com

The listening device being shown at the U.N., 1960.
Cryptomuseum.com

Lev designed a second device capable of sensing the vibrations in window glass resulting from conversations within a room. He did this by directing an infrared beam at the window and focusing it at a spot of optimal resonance; the ray would be reflected back to an interferometer and a photo element. The system was hard to detect and it proved effective at distances up to 1600 feet in clear weather. It was called the Buran system.

In June 1947, Lev's case was reviewed and he was freed. Upon his release, he was given a high honor — the Stalin Prize for recognized work in cultural, scientific, and technical areas. However, because of his work on sensitive and secret projects, his freedom was very limited. His passport would not permit him to leave Moscow. Further, he remained under heavy surveillance and had to be careful with whom he associated. He even learned to speak without moving his lips to foil lip readers. All ties with relatives had been severed. He did have a short-lived marriage in 1948 to a younger co-worker that produced twins.

For much of the rest of his life, he lived in difficult surroundings sharing residential space with other families in small apartments or, at time, living in a single small room. He didn't he have a facility or much workspace for personal research or projects. He did very little with his musical devices because building such instruments was frowned upon by the ever-watchful government. And all the evidence and documentation of Lev's earlier accomplishments had been "erased" — he no longer had a heritage or legacy.

Clara Rockmore and Lucie Rosen continued to perform into the 1950s and staunchly defended the Theremin as a serious musical instrument deserving of respect. Lavinia joined the American Ballet Theater. By 1953, She finally gave up on rejoining Leon and remarried. She worked with the Haitian folkloric dance artists and eventually moved to Haiti in the mid 1950s. Lavinia, who had at times been overtly critical of the Haitian leadership, died under suspicious circumstances in 1989.

The Theremin was used on radio and by Hollywood including the movie *Lady in the Dark*, Alfred Hitchcock's *Spellbound*, Billy Wilder's *Lost Weekend*, *The Spiral Staircase*, 1950s science fiction movies, and throughout the *Green Hornet* radio series from the late 1930s to the early 1950s. The Theremin appeared on 1950s television shows including Y*ou Asked For It*, Walt Disney's *Mickey Mouse Club*, *The Loretta Young Show*, *The Colgate Comedy Hour*, and many more. Many of these performances were done by Samuel Hoffman.

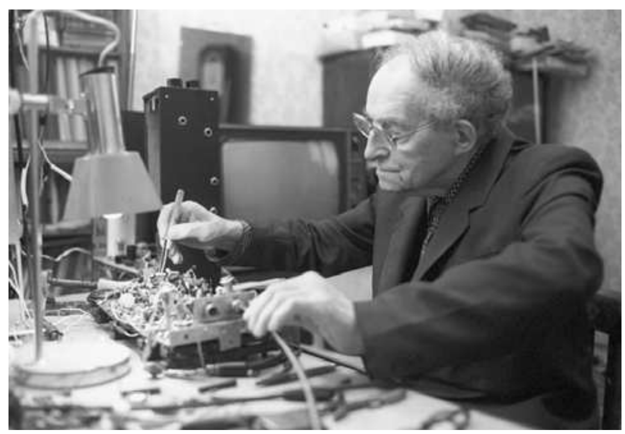
Robert Moog demonstrating his Theremin, 1954.
Theremin World

In his mid teens, Robert Moog was fascinated with the Theremin and built his first from a magazine article. He continued to refine his conception of the instrument and in January 1954, published his own article in Radio and Television News outlining plans for a home-built Theremin. While in college studying engineering and physics in the mid 1950s, he formed the R.A. Moog Company out of his bedroom and began selling ready-made Theremins. He developed several models with innovations not found in Theremin's designs including an "overtone selector" and a "synthetic format" that produced different timbres. In 1957, he began designing transistor models and, in 1961, published an article in Electronics World with a schematic and construction plans for a completely transistorized model. His work evolved into an envelope generator constructed with voltage-controlled oscillators, amplifiers, and filters. The generator enabled the attack, decay, sustain, and release of the sound envelope to be precisely configured. By 1965, this evolved into the Synthesizer. The company still produces Theremins and Synthesizers. Moog Synthesizers have found a place in mainstream music in the way Theremin could only dream about.

Paul Tanner playing his Electro-Theremin, a.k.a. Tannerin, 1960s.
MoogMusic.com

Paul Tanner, a session trombonist in Hollywood, saw opportunities for Theremin players in Hollywood but felt the Theremin was too hard to master. So he decided to design his own Theremin-like instrument which he called an Electro-Theremin, also nicknamed the "Tannerin." He placed a commercial variable oscillator into a two-foot long narrow wood cabinet and attached a piano wire to the oscillator to change the pitch. The wire was routed through a small hole at one end of the top where it was attached to a mechanism with a contact switch that slid across the length of the cabinet. When the finger touched the contact a sound was produced and, when the contact was released, the sound stopped. As the contact slide mechanism was moved along the cabinet length, the attached wire also connected to the oscillator changed the pitch. The top of the cabinet had markings with the musical scale. The output of the oscillator was input into a Heathkit EA-2 amplifier. This differed greatly from a true Theremin in that it was not spatially controlled, nor did it use heterodyning principles to produce pitch or volume. Tanner was able to get studio work with his Tannerin in the late 1950s through the 1960s. His work included the *My Favorite Martian* television series and Beach Boy recordings including "Good Vibrations." When he no longer needed the instrument, he believed it was of no value as he felt, by then, synthesizers could do everything his instrument could do and more; so he donated the device to a hospital for hearing testing and audiology.

When Mikhail Gorbachev came to power in 1986 and instituted economic and political restructuring (perestroika) and freedom to speak out (glasnost), Lev was able to finally able to resurrect a small portion of his legacy. In 1986, at Robert Moog's urging, he was able go to Paris to speak at the UNESCO "Synthesis 89" symposium. In 1990, he was able to attend the Stockholm Electronic Music Festival and the next year he was invited and able to attend a Stanford University event to speak, and once again performed with a rendition of "Midnight in Moscow." After the event he was flown to New York so filmmaker Steven Martin could get shots of him at various locations to be used in the documentary *Theremin: An Electronic Odyssey*. In New York, Lev was briefly reunited with Clara Rockmore. Two years later, on November 2, 1993 the documentary premiered across Britain on BBC. The next day, 97 year-old Lev Sergeyevich Termin passed peacefully in his sleep.



Lev Sergeyevich Termin, 1896 -1993.

References:

Glinsky, Albert; Theremin Ether Music and Espionage; University of Illinois Press; 2000 The definitive reference for Leon Theremin. This article is primarily a skipping stone summary of this book. It is highly recommended that anyone seeking more details read this book.

Harrison, Arthur website; www.theremin.us; Offers detailed technical information about the original RCA Theremin and customizations done for Clara Rockmore and Lucie Rosen.

RCA Theremin website; RCATheremin.com; A comprehensive site for information about the RCA Theremin and other Theremin instruments. Also includes the RCA Theremin registry.

Theremin World website; www.thereminworld.com; The primary site used by Theremin enthusiasts. Has detailed RCA Theremin technical information including schematics and cabinet specifications.

Wikipedia articles: *Clara Rockmore*; *Leon Theremin*; *Theremin, The Thing (listening device)*

◊

Building a Theremin

By Richard Watts

Fascinated with the idea of constructing a vacuum tube Theremins, in 2010 I decided to build one. After considerable research I opted for a design by Mark Keppinger as his design is highly regarded in the Theremin community. At the time, several had been built or were in progress, and a small community of Keppinger Theremin builders shared information on a Yahoo group.

The Mark Keppinger designed Theremin. Power chassis right., Oscillator chassis left. Pitch coil far left, volume coil center.

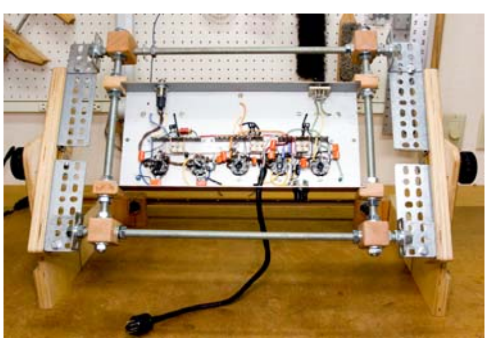
I contacted Mark and let him know my intentions. He had made fifteen chassis sets a few years earlier and was now giving his last unused sets to new builders. When I contacted him, he had only one set remaining and was gracious enough to have it sent to me. The Yahoo group was helpful in providing technical information. The schematic, parts list, and link to the Yahoo group is available at http://www.thereminworld.com/Keppinger-Theremins. The schematic and theory of operation are on the next page.

Since there were no more chassis sets available, another group member said he would make more but needed dimensional drawings of each chassis. None were available, and since I hadn't started construction yet, I created CAD drawings and posted them to the group for his use. I then started the build by painting the chassis, and creating and affixing decals.

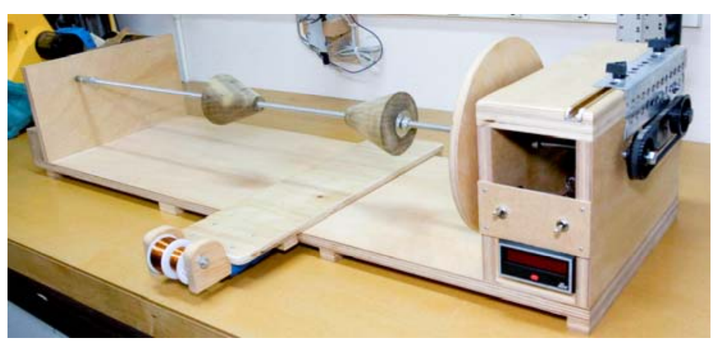
After acquiring parts which are readily available, I constructed the oscillator and power chassis. Since the chassis didn't have mounting holes, to hold the chassis I modified my home-made chassis holder by adding a cross screw vice attachment that clamped the chassis in place. The chassis holder is fully rotational and held it securely in any position.

Five coils needed to be wound. The specifications for coil construction are included in the parts lists at the link cited above. To wind the coils I built a coil winder. I included a counter driven by a magnetic switch to count rotations. The motor speed is adjustable by changing gear ratios on the side. The motor is mounted to a bracket that can be adjusted to tighten the belt. Cones, which hold each end of the coil form, are fully adjustable along the threaded rod. The coil forms are tubes of high density cardboard that hobbyists use for rocket building.

I completed and tested the chassis sets in 2011 but still needed antennas. I considered various alternatives including making my own by bending tubing, but wasn't confident I could do it well enough to produce satisfactory results. So I set the Theremin aside and tackled other projects. Finally in 2015 I found that the Yahoo member who was making chassis sets also makes replica RCA Theremin antennas plated in nickel as the originals were. Plus he provided mount fittings that enable the antennas to be removed also like the original RCA Theremin. So I ordered a set.



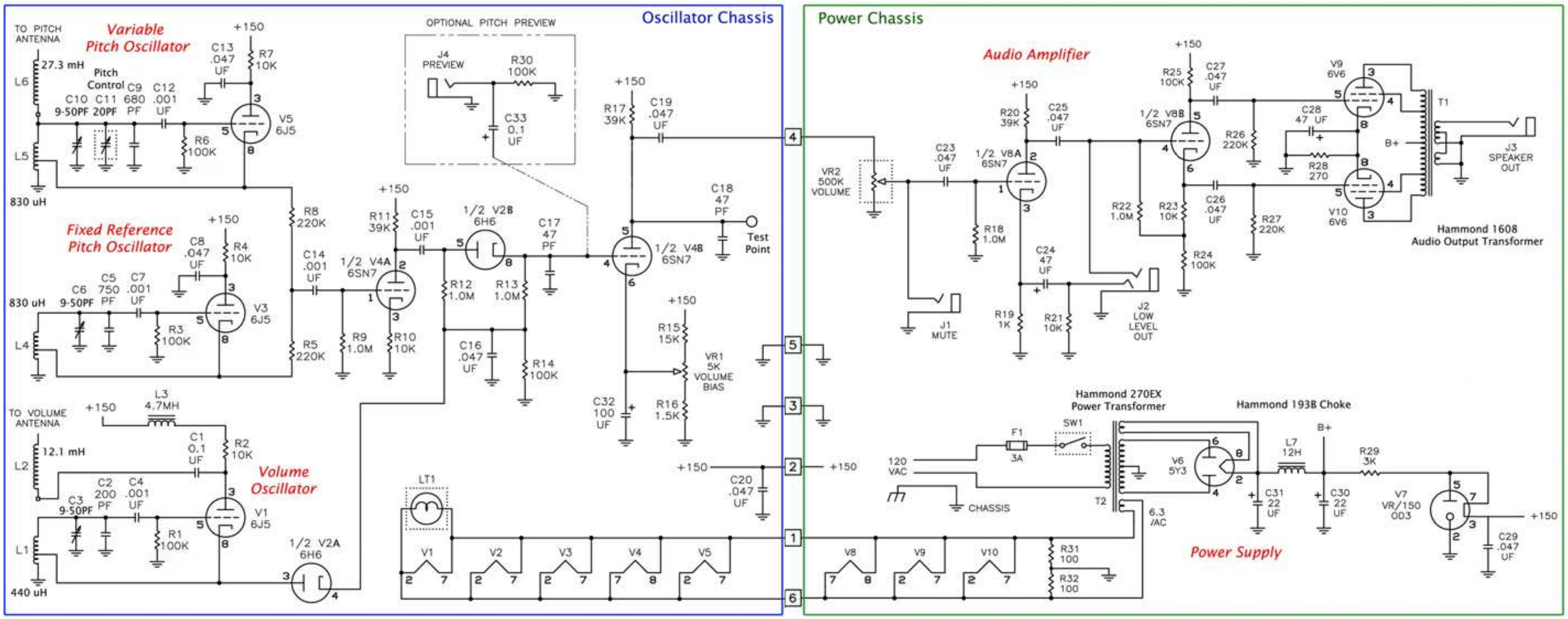
Home-made chassis holder with cross screw vice attachment for holding chassis with no mounting holes. Oscillator chassis is shown.



Home-made coil winder with rotations counter. Speed is adjustable by changing gear ratios on the side. Coil form mounts between cones which are tightened on the threaded rod.

Keppinger Tube Theremin

Adapted from drawings by Jeff Sparks, 2008



Theory of Operation

The two pitch oscillators are basically Hartley oscillators utilizing triodes (V1, V3) with the output taken from the cathodes. In both pitch oscillators, the plate resistor (R4 and R7) is, from RF view, bypassed to ground via C8 and C13 so that they produce a steady amplitude. The reference pitch oscillator is fixed at about 180 to 190 kHz for “bass tuning.” The pitch response of the instrument can be adjusted from “bass tuning” to “concert tuning” by changing C5 and C8 to 430pf which will increase the reference pitch oscillator to 205 to 215 kHz. The pitch antenna is connected via L6 to the tuning circuit of the variable oscillator; moving the hand closer to the antenna increases capacitance which lowers the frequency of the tuned circuit. The output of each pitch oscillator is heterodyned (mixed) at the junction of R5 and R8; the difference frequency is within audible range. The resulting signal is buffered at V4A and V2A.

The volume oscillator also is a Hartley oscillator with the output taken from the cathode, but operates differently than the pitch oscillators. The oscillator frequency (about 420 kHz) remains unchanged since there are no variable parts in the tuned circuit between the grid and cathode of V1, except the trimmer C3 to set the initial frequency. The reactance of RF choke L3 increases the volume oscillator amplitude to insure enough swing for the input to the 6H6 bias circuit. The volume antenna coupled to L2 determine the oscillator’s amplitude; this doesn’t affect the oscillator frequency because it is isolated from the tuned circuit by 6J5 (V1). Moving the hand away from the antenna reduces capacity resulting in maximum amplitude. Conversely, the closer the hand gets to the antenna, the increase in capacitance reduces oscillator amplitude.

The output from the volume oscillator is rectified by one-half of the 6H6 (V2A) resulting in a DC voltage or 20v to 30v depending on the oscillator amplitude; this DC voltage determines the bias of the other half of the 6H6 (V2B) and, in turn, the grid bias of the 6SN7 (V4B). The bias of V4B can be adjust by the Volume Bias control (VR1); this determines the proper response of the volume antenna to the hand. The signal is applied to the grid of V4B. A unique part of the design is this volume control; Mark used a grid bias cut-off circuit that clips the audio signal until it doesn’t exist and is very effective.

Audio is then amplified via an intermediate stage (V8A), and push-pull final audio stage (V9, V10) with the requisite phase inverter. The power supply provides 150VDC regulated by an OD3 (V7).

Now I needed a cabinet. I was free to design a cabinet anyway I wanted, but opted for a cabinet that closely resembled the original RCA Theremin in style and dimensions. Dimensional drawings of the RCA Theremin can be found at http://www.thereminworld.com/Article/13286/rca-theremin-component-values-and-cabinet-dimensions.

Because of differences in Keppinger chassis size compared to the RCA, I wouldn't be able to fit the Keppinger chassis into an RCA style cabinet without alterations. I opted to keep the dimensions of the front profile identical to RCA's and found I could do that if I added two inches to the depth. To do this, I kept the size and slope of the front face the same as the RCA and added the two inches to the top piece. The original RCA had a single slot in the top for ventilation. Keppinger Theremins run hotter than the RCA s. So, adding two inches to the top enabled me to add two additional ventilation slots. I also added ventilation holes in the bottom and center shelf. With these changes, ventilation is more than adequate.

Original RCA Theremins. Two finish colors were available.
Matrixsynth.com

Because of the different location of the controls on the oscillator chassis from RCA's, I had to reverse and adjust the placement of controls as well as the power and mute switches on the front panel. I wanted the lamp, and pitch and volume controls together on a panel like RCA so I mounted them on a black acrylic panel. Since the lamp and volume control are on the lower power chassis, I had to mount a second volume control and lamp on the panel. I used Molex connecters to disconnect the chassis control and lamp and connect the ones on the panel. When the power chassis is on the bench, the volume control and lamp in the chassis can be easily reconnected. I used ball toggle switches like the RCA's for power and mute; and I was able to find RCA Radiola knobs that matched the original.

The cabinet during construction.

RCA Theremins were typically paired with the RCA model 106 floor speaker, yet most custom Theremins made by Leon Theremin included a speaker in the lower part of the cabinet. So, to conserve space, I opted to mount a speaker under the cabinet as well. I wanted to stay with the RCA tapestry grill cloth style, so I designed the speaker case taking design cues from the RCA model 103 speaker and used a reproduction RCA 103 grill cloth. All the moldings except the "rope" molding were made with a router. The speaker is an 10" Jensen.

The original RCA was made from mahogany, so I acquired some 4/4 and 8/4 mahogany for the construction. I used dowel joinery, there is no metal joinery used. I filled the grain and applied a lacquer finish as did RCA. I opted to keep the finish natural so no color or toners where applied. The color will darken with age.

Once fully assembled and aligned, it sings beautifully.




The completed Theremin.

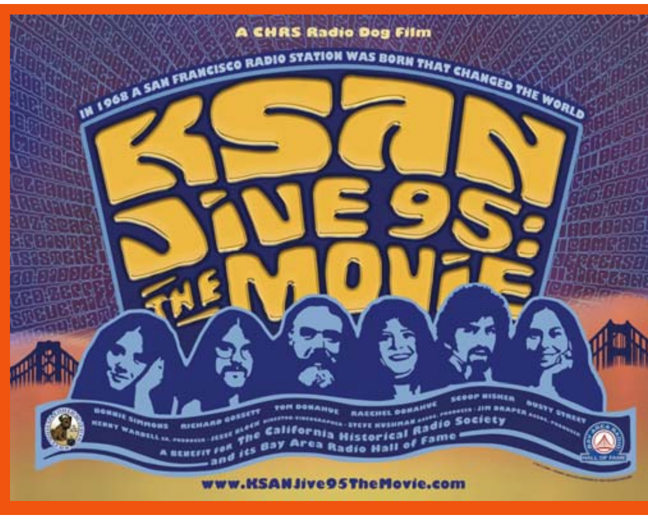
◊

KSAN Jive 95: The Movie

Our CHRS Radio Dog Production, **"KSAN Jive 95: The Movie"** continues in production. But making a feature length documentary is costly. We are seeking to raise $150,000 to produce this film. The KSAN Jive 95 story is perfect for CHRS to tell and immortalize in film as it is an important part of our mission to preserve and present local radio history. KSAN, during the period 1968-1980, was pivotal in the development of our popular culture. This film will raise awareness and refresh remembrances of a time when a radio station could create change and really make a difference in so many ways.

Part of our recent grant from the Rex Foundation was earmarked toward the KSAN Movie project. We commissioned famous poster artist Wes Wilson for a movie poster. Wes and his daughter Shirryl Bayless collaborated to create this outstanding poster.

Now it's your turn to help. Please visit www.ksanjive95themovie.com and see how you can get great perks for donating to this project and help to preserve the KSAN Jive 95 legacy.

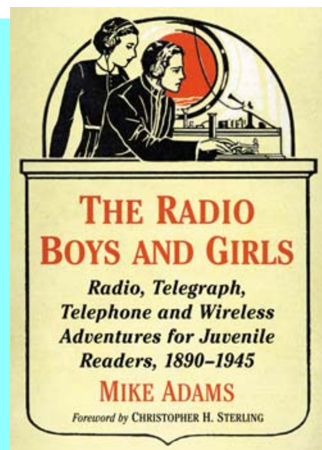


CHRS Publications

The Radio Boys And Girls—Radio, Telegraph, Telephone and Wireless Adventures for Juvenile Readers 1890-1945 is the latest book by Mike Adams, It captures the genre of series fiction about wireless and radio was a popular in young adult literature at the turn of the 20th century and a form of early social media. Before television and the Internet, books about plucky youths braving danger and adventure with the help of wireless communication brought young people together. They gathered in basements to build crystal. They built transmitters and talked to each other across neighborhoods, cities and states. By 1920, there was music on the airwaves and boys and girls tuned in on homemade radios, inspired by their favorite stories.

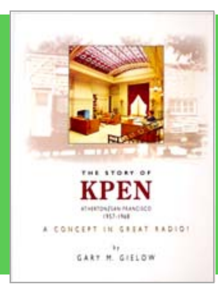
This book covers more than 50 volumes of wireless and radio themed fiction, offering a unique perspective on the world presented to young readers of the day. The values, attitudes, culture and technology of a century ago are discussed, many of them still debated today, including immigration, gun violence, race, bullying and economic inequality.

Available now at Amazon.com

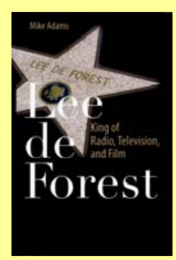


The Story of KPEN: A Concept in Great Radio! CHRS member and Broadcast Legend Gary Gielow has written a new book chronicling the tales of two young men from Stanford, he and James Gabbert, who brought Stereo and new ideas to the FM radio band in the late 1950s and 1960s. This book is the definitive history of KPEN 101.3 FM, the 2015 BARHOF Legendary Station. 100% of the proceeds benefit CHRS.

Available in the Museum Store or on the website.



Also available in the museum store

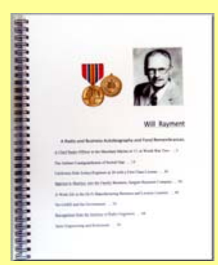


Lee de Forest

Bay Area Radio

Behind the Front Panel: The Design and Development of 1920's Radio by David Rutland has been re mastered by Richard Watts for CHRS. With emphasis on radio technology, Rutland describes the development of 1920s tubes and radio circuitry designs by De Forest, Marconi, and other inventors and manufacturers. A classic!

Buy at Amazon.com



Will Rayment

KSAN Live Jive CD

◊

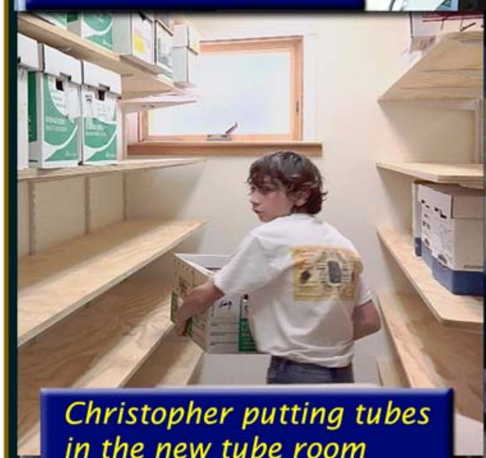
Lots Going On at CHRS

Steve Kushman Broadcast Legends - Legend of the Year

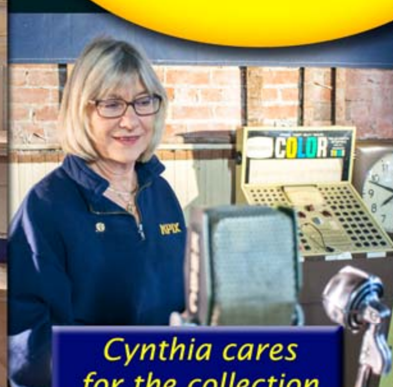
Society of Broadcast Engineers - Chapter 40 Dinner

Radio Theory Class

Seth in the new shop



Christopher putting tubes in the new tube room



Cynthia cares for the collection

Show & Tell Day — Art shows his1950s spark set

Holiday Luncheon

Philip helps new member