Colorado Radio Collectors — Antique Radio Club

The FLASH!

Volume 21, Issue 4 | The July 11th meeting is at Philip Miller Library in Castle Rock | July/August

Dedicated to the Preservation and Education of Wireless, Radio, Television and Associated Equipment

The Mineralogy and Construction Of Crystal Detectors

Martin Guth

As a participant in the hobbies of collecting antique radios and minerals from around the world, I noted a crossover point between the two in the form of early radio detectors based upon various different minerals. Intrigued by this concept, I began an investigation as to which minerals were used and how they function electrically as a diode.

Since the electrical properties of detector diodes were discussed in David Laude's article on the history of detector development, I won't get too deep into the theory of how diodes work. The focus here will be on the chemical characteristics of two of the most common detector minerals. Also, we will have a look at a process I developed to construct a mounted galena detector crystal assembly similar to those used 100 years ago, and then will see how galena compares electrically with germanium and silicon diodes.

The Minerals

Beginning with early experiments in the conductivity of minerals by Professor Karl Ferdinand Braun and his discovery of rectification in 1874, a number of scientists began investigations into which minerals have properties suitable for this purpose. In 1902, Greenleaf Whittier Pickard discovered that mineral rectifiers could be used as detectors in radio receivers and the race was on to determine which provided the best results in this application. Many efforts were focused on minerals suitable for detectors, while others directed their research towards higher current devices for use as power supply rectifiers. In the early 1900's, the list of minerals that exhibited the property of rectification ran up to over 250, most not practical for radio applications. Some were not sensitive enough, others proved too costly or rare for mass production while many were too unreliable for long term use. Two of the most common minerals with all the desirable characteristics are galena (chemical formula PbS) and pyrite (FeS), commonly known as "fool's gold". But not all pyrite and galena specimens are suitable for detector use as there are many factors that may enhance or inhibit rectification. Since I have a number of specimens of both, I decided to test them all using a Philmore Little Wonder crystal radio set as a gauge of relative performance.

In November 2009 I was on a rockhounding trip to New Mexico, visiting the Blanchard mine about 35 miles east of Socorro. Part of the Hansonburg Mining District on the north end of the White Sands Missile Range, the Blanchard mine is a treasure trove of minerals for collectors. There are some 90 different minerals in the area, some of which were commercially mined for a short period in the early 1900's. While primarily interested in silver, the first miners encountered large amounts of quartz, barite and of particular interest here, galena. Since this is a remote location without railroad access, all attempts at profitable galena mining as an ore of lead met with financial disaster. With vast amounts of galena in more readily accessible areas in Missouri and Oklahoma, it made little sense to haul lead out of such a remote location and the mines were left to the collectors.

My first task was to evaluate galena and pyrite samples from my collection by placing each piece on a sheet of aluminum foil connected to the radio with a clip lead, then probing around the crystals with a nickel-plated needle also connected to the radio, simulating a "catwhisker". After many hours of experimentation it became obvious that galena from some locations worked better than others, and some didn't work at all. Fortunately, while I was in the

(Continued on page 3)

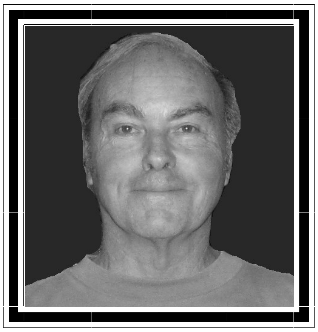
Inside this issue:

COLORADO RADIO COLLECTORS ANTIQUE RADIO CLUB

Founded October 1988

Message from the President

Greetings fellow club members! How is your summer going? Anyone finding any rare radios or other related items?



We are having a talk and a DVD video on plastic radio cabinet repair and refinishing. Marty Phillips, our VP, will talk about his experiences on this subject. Should be very interesting.

Our next main topic will be the upcoming club picnic and auction at Tectonic. Yes, its that time of year again! Our auction and picnic last year was a smashing success. Looking forward to this one, some real treasures might turn up!

See you all at the next meeting in Castle Rock.

Tom

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Upcoming Events

7/11—CRC Meeting
9/6—Labor Day
9/12—CRC Meeting
9/19—Annual Auction/Picnic

Meeting Locations (Unless noted otherwise)

Littleton	Castle Rock
January	March
May	July
September	November

CRC MEETINGS

Meetings are held on the 2nd Sunday of every other month starting in January (except 3rd Sunday of May) at 1:00 pm. The meetings consist of business, "show & tell", raffles, auctions, swap meets, technical discussions and other subjects of interest

CRC MEMBERSHIP

Annual membership in the CRC runs from July to June. Dues entitle members to attend meetings, "The Flash!" our newsletter, discount book prices, participation in our spring show and Fall auction. Current annual dues are $12. New memberships will be prorated to the following June.

Changes to Show Scoring & Categories.

By Rich Kuberski

The following recommendations are proposed.

1. Create new MILITARY category.
2. Separate KIT and HOMEBREW into 2 categories.
3. Break ACCESSORIES into two categories; ACCESSORIES and TEST EQUIPMENT.
4. No changes to scoring.

2010 CRC Auction and Picnic

The 2010 CRC Auction/Picnic will be September 19th. Same location as the past few years—The grounds of Tectonic Management Group in Wheat Ridge.

(Continued from page 1)
Blanchard mine I ignored all the pretty blue fluorites and instead searched through the rubble for small galena crystals and rocks with galena crystals attached. I also have specimens from Missouri, Oklahoma, Peru, Bulgaria and a few unknown locations and all behaved differently. This discrepancy in performance may be attributed to differences in trace mineral content as well as the temperature and pressure conditions under which the crystals formed. Galena can form cubic, octahedral or dodecahedral crystals depending on the environment in which they are created. In addition, during the millions of years after formation minerals can be exposed to heat, acids and/or oxidizing agents that can alter surface and internal chemistry.

As I have access to an electron microscope with X-ray fluorescence capability, some analysis was in order. Basically, a sample is exposed to a beam of high energy X-rays of a certain wavelength. Atoms in the crystal structure will absorb these X-rays, causing electrons to jump to a higher energy orbit. This is an unstable state, and the electron quickly drops back to its previous level while emitting an X-ray photon of a specific wavelength related to that particular atom. This photon may also knock other electrons within the atom into a temporarily higher energy state, leading to the fact that many atoms have multiple spectral lines showing up in the X-ray fluorescence that results. One limitation of this process is that different atoms may emit X-rays of nearly the same wavelength, making it difficult to determine what is what. Many times one of the secondary lines is used to verify the result.

Figure 1 shows the spectral signature of two different galena samples. The plots show emitted X-ray energy on the X-axis, with relative abundance on the Y-axis. Here we have both lead (Pb) and sulfur (S) running off scale as I had the gain turned up to show the trace elements. Note that Pb and S pretty much overlap, although they are distinct at lower gain settings. The two samples in this data are a piece I collected in the Blanchard mine and one from a detector I purchased online. As it turns out, most of the Blanchard galena makes for excellent detectors while the purchased detectors performed poorly. They do seem similar in chemical content with one notable exception in the form of aluminum. The Blanchard crystals generally have a significant amount of aluminum while the other from an unknown location does not. Both silver and aluminum impurities have been noted as affecting the performance of galena detectors, although detailed data is lacking.

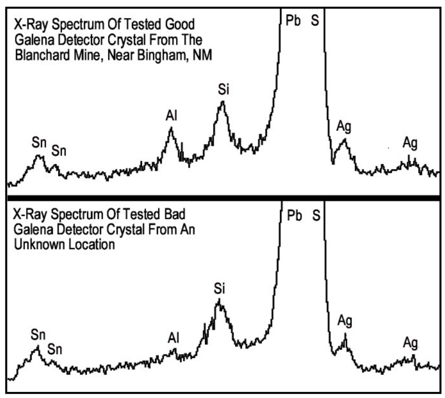


FIGURE 1: Comparison of two galena samples via X-ray fluorescence.

Another mineral commonly used for crystal detectors is pyrite. Again, I have specimens from multiple locations and have tested them all with about the same result as the galena trials. Pyrite from Peru and Colorado seems to work nicely, while specimens from Ohio and Spain are completely useless. Figure 2 shows a significant difference between Peruvian pyrite that works well and a Spanish one that does not. The Peruvian specimen contains more iron, silicon and a trace of magnesium while the Spanish material contains more aluminum. Any or all of these may affect electrical performance in use as a rectifier. I thought a measure of surface resistance might be interesting, so I placed ohmmeter probes about a quarter of an inch apart on pyrites from Peru and Spain. Peruvian pyrite typically produced a resistance from thousands to tens of thousands of ohms whereas the same measurement on Spanish pyrite indicated only a few ohms, making it a good conductor not suitable in detector applications where a semiconductor is required.

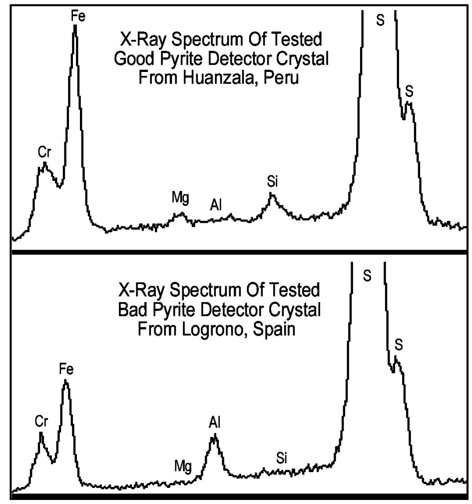
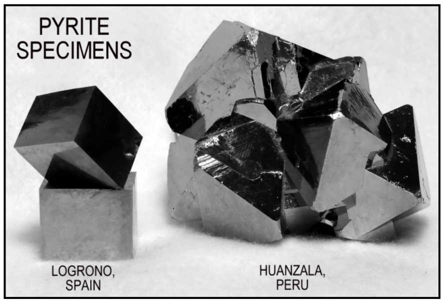


FIGURE 2: Comparison of two pyrite samples via X-ray fluorescence.

It is interesting to note that pyrite specimens from Spain form virtually perfect golden cubes, sometimes interlocked together to form fine mineral specimens. Pyrites from Peru can be of multiple different crystal shapes, most commonly octahedrons but also including cubes. As with galena, conditions at the time of formation plus trace impurities can strongly alter the characteristic shape of the crystals as well as electrical characteristics.

Having re-created some of the experiments done by the early pioneers of detector technology, it became obvious that empirical testing of any mineral should be done prior to use as a crystal detector. Most of the galena I gathered from the



Blanchard mine was from 400 feet in, but the tunnels go on for miles and perhaps in the murky depths of the mine there may be crystals that behave differently. For example, some of the pieces I obtained near the mine entrance did not perform as well, possibly due to surface oxidation due to exposure to varying atmospheric conditions not found deeper in the mine

Constructing A Galena Detector For Use In Antique Crystal Radios

Having purchased several dud galena detectors via the internet I decided to attempt to make my own replicas of those found in the old crystal sets. The Philmore Little Wonder radio I obtained had an original detector from the late 1930's I could use as a model, so I investigated what it would take to build my own using galena I collected myself. Since the electrical properties of galena may be affected by high temperatures, I wanted to use the solder originally used called Wood's metal to hold the crystal. This material melts at 70C vs. 190C for conventional tin/lead solders. Unfortunately, it consists of bismuth, lead, cadmium and tin with the cadmium and lead being out of favor by the EPA. There is an alternative called Field's metal sold by the inventor, but a foot long wire 1/8" in diameter is about $45 as it contains indium, an expensive metal in high demand for use in large screen TV's among other applications. I was successful in obtaining nearly half a pound of Wood's metal pellets for $2 on Ebay, but had to pay $15 in shipping charges from Skytyvkar, Russia, some 600 miles northeast of Moscow. Having thus obtained a sufficient quantity for process development, I turned my kitchen into a galena detector fabrication facility.

The next step was to create a mold that would allow the solder to fill a cavity of the desired size. Most detector mounts will accept a mounted galena crystal that's just under a half inch in diameter. Height is not very critical, but for one radio I have it needed to be roughly 1/4" to 3/8" inch high so that defined the shape of the mold. I have a friend with a machine shop, and we made up a mold out of an aluminum cylinder as shown in Figure 3.

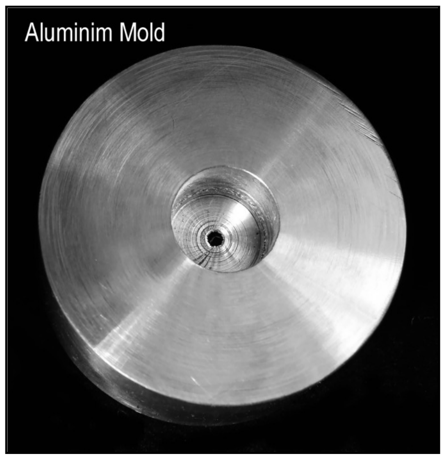


FIGURE 3: Aluminum mold for galena detector solder.

Using a flat end mill, we created a pocket 3/8" deep and 7/16" in diameter with a smaller hole in the bottom to accommodate a drill bit used to shove out the completed assembly from the back side after the solder hardens. The good news is that like most solders, Wood's metal does not adhere to aluminum very well. The bad news is that it is one of the few substances that expand upon cooling. Therefore, using the mold as shown would result in a detector stuck in the mold. This was verified by my first attempt, so modifications had to be made. One could make this out of two pieces that bolt together and can be taken apart for easy removal, and my Philmore detector has marks on the solder indicating that is how they were made. Another solution is to use a dremel bit to deform the hole into a more conical shape, so before making a more complex mold I tried this first. However, even with a significant taper to the sides of the cavity the surface roughness of the cavity walls makes removal very difficult. I tried silicone grease as a mold release agent, but that was no help at all. In the end, I cut out a small piece of aluminum foil to cover the bottom of the cavity to prevent the solder from running out (which it will). Then, I cut a strip of foil several inches long and rolled it tightly around a 3/8" drill bit shank. When removed from the drill bit, it expanded to nicely fit the cavity, thus lining the wall with several layers of soft foil that I thought should make removal much easier.

To heat the aluminum block, I placed it on an electric stove heating element using a surface temperature probe to measure the temperature at the top of the mold near the cavity. The intent is to keep it under about 100C to avoid excessive oxidation of the solder and damage to the galena. Figure 4 shows the mold on the stove with the aluminum foil wall covering and a molten blob of Wood's metal contained.

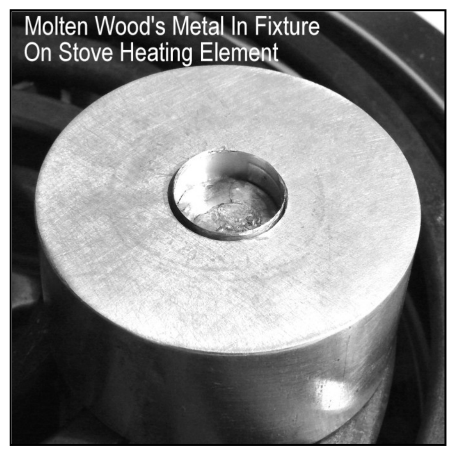


FIGURE 4: Aluminum mold with molten solder.

Because of the thermal mass of the aluminum this takes a while to cool down, so I used a small parts holder with an alligator clip as the alignment tool to hold the galena in place. At first I used some hot glue to attach the galena crystal to the end of a toothpick that would be held by the parts holder.

(Continued from page 4)
Although a lead ore, the density of galena is far below that of Wood's metal and the crystal will float like a cork without somehow being restrained. This actually did work after a fashion, but even at 70C the glue gets soft enough to let go. Also, there are no solvents that dissolve the glue as it's actually a plastic, so this effort was abandoned. I next tried attaching the galena to the toothpick using water soluble Elmer's glue. This worked better and I could get crystals to hold still while the solder hardens.

Even at this low temperature there is some surface oxidation of the Wood's metal, so I tested five different fluxes. There is a special flux designed for this called Baker's fluid #3, but this is nasty stuff to handle and contains materials that attack the galena. Rosin flux, plumbers flux of two types and Kester liquid flux all contain ingredients that render a good crystal useless. And No-korode flux corrodes.

I spent several days making bad detectors, but the solder can be re-used many times and very little of the original supply was consumed. Nothing appeared to be working so I tried one last process: get rid of the flux , the adhesives and the part holder. I heated the mold enough to just melt the solder, and before any significant oxide scum formed on the surface I removed the mold from the burner and placed it on the stove top to allow it to cool. I didn't want it to cool down so fast that I didn't have time to place the crystal, hence the mold is larger than it appears necessary just for the extra thermal mass. Once removed from the burner I used a fine pair of tweezers to hold the crystal in place as shown in Figure 5. The solder will actually wet the galena when pushed through the oxide film, providing good electrical and mechanical adhesion.

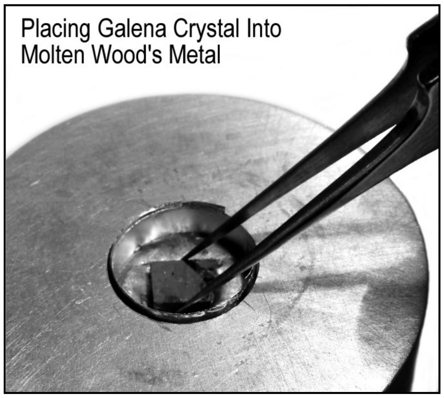


FIGURE 5: Placing the galena crystal into molten solder.

After the solder cools and hardens, you can let go of the tweezers and allow it to cool to room temperature. At this point you are ready to poke through the back side hole and see if the detector will come out. Usually, it breaks loose inside but still won't quite make it out of the hole. Positioning the soldered part at a spot where it's loose inside, I carefully peel out the strip of foil surrounding it. This now creates a gap between the cavity wall and detector that is now easy to push out. The finished detector in the mold in Figure 5 is shown in Figure 6.

FIGURE 6: Completed galena detector assembly.

By keeping the temperature to a minimum and acting quickly to place the galena, the result is a mounted crystal that has not been overheated or exposed to chemicals that ruin it's electrical behavior. It comes out just the right size for any detector cup I've seen to date and a crystal that tested good before mounting tests good afterwards. In this case, this is by far the most sensitive galena detector I have ever seen, easily beating out my Philmore detector and any germanium diodes I have tried. Also, virtually the entire surface is a hot spot, with one local station coming in loud enough it could stand a volume control. But, we're not done yet.

In testing galena for performance in crystal radios, I tried to modify crystals of marginal sensitivity. Galena crystals are easy to shear apart along a crystal fracture plane, and larger pieces may be cut down to size using a sharp razor blade and a small hammer. This can expose a fresh crystal face that's never seen daylight or air before. I have found that freshly fractured faces like this can be very good as is the case of the detector in Figure 6. On low performance crystals I have tried sandblasting, chiseling chunks off and even sandpaper all to no avail. I even tried all of these processes on tested good crystals, the result being a dead detector. A clean break along a fracture line yields the best result, and I intentionally mounted a crystal with a 1/8" chunk sticking up above the solder. I was able to shear this off and it works very well even though it was marginal before I removed part of the crystal.

FIGURE 7: Completed galena detector assembly in a Pandora crystal radio.

(Continued from page 5)

Electrical Characteristics of Galena vs. Germainium and Silicon Diodes

Part of the experiment was to sample various diode types in use as a detector, with relative performance being judged by earphone volume. A number of small signal silicon and germanium diodes were tested, as well as large silicon rectifiers and Schottky diodes. The results were not always predictable as some of the large power diodes worked fairly well while certain small signal ones did not. There is even a large degree of variability between diodes from the same lot, so trial and error is the rule. The bottom line is that in general of all the packaged diodes tested, the germanium types are superior. However, some germanium diodes were not as good as some silicon diodes, and neither perform as well as a galena diode from the Blanchard mine. To verify this via electrical measurement, I rigged up a scope as a curve tracer and compared I-V curves for the three diode types, the result being shown in Figure 8.

Of the diodes tested, it is obvious that a silicon diode has the highest threshold voltage before electrical conduction begins, in this case about 400 to 500 mV. The germanium diode is better with significant conductivity in the 100 to 200 mV range. The galena diode, while not a particularly good rectifier, does have the performance where it counts in a detector. With virtually no measurable threshold voltage, the tiny signals from an aerial alone are sufficient to be rectified. Even though it is barely a diode as measured here, galena can outperform silicon and germanium as a detector in crystal radios. In other words, a needle on a rock makes a fine diode in this application.

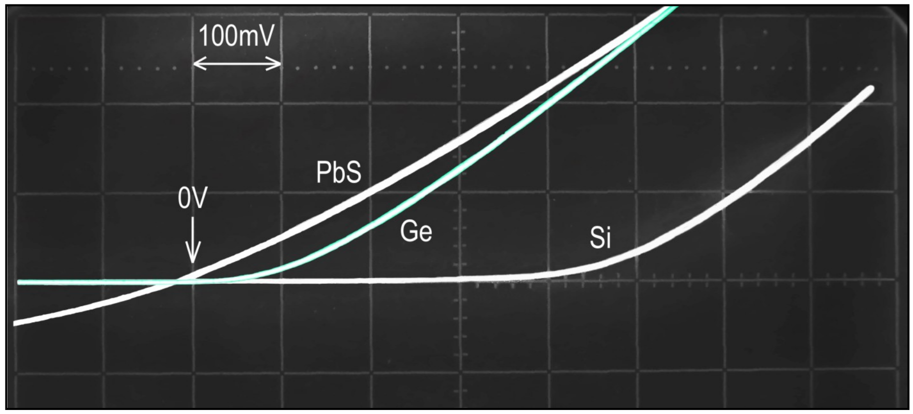


FIGURE 8: I-V Curves of Galena and Small Signal Germanium and Silicon Diodes.

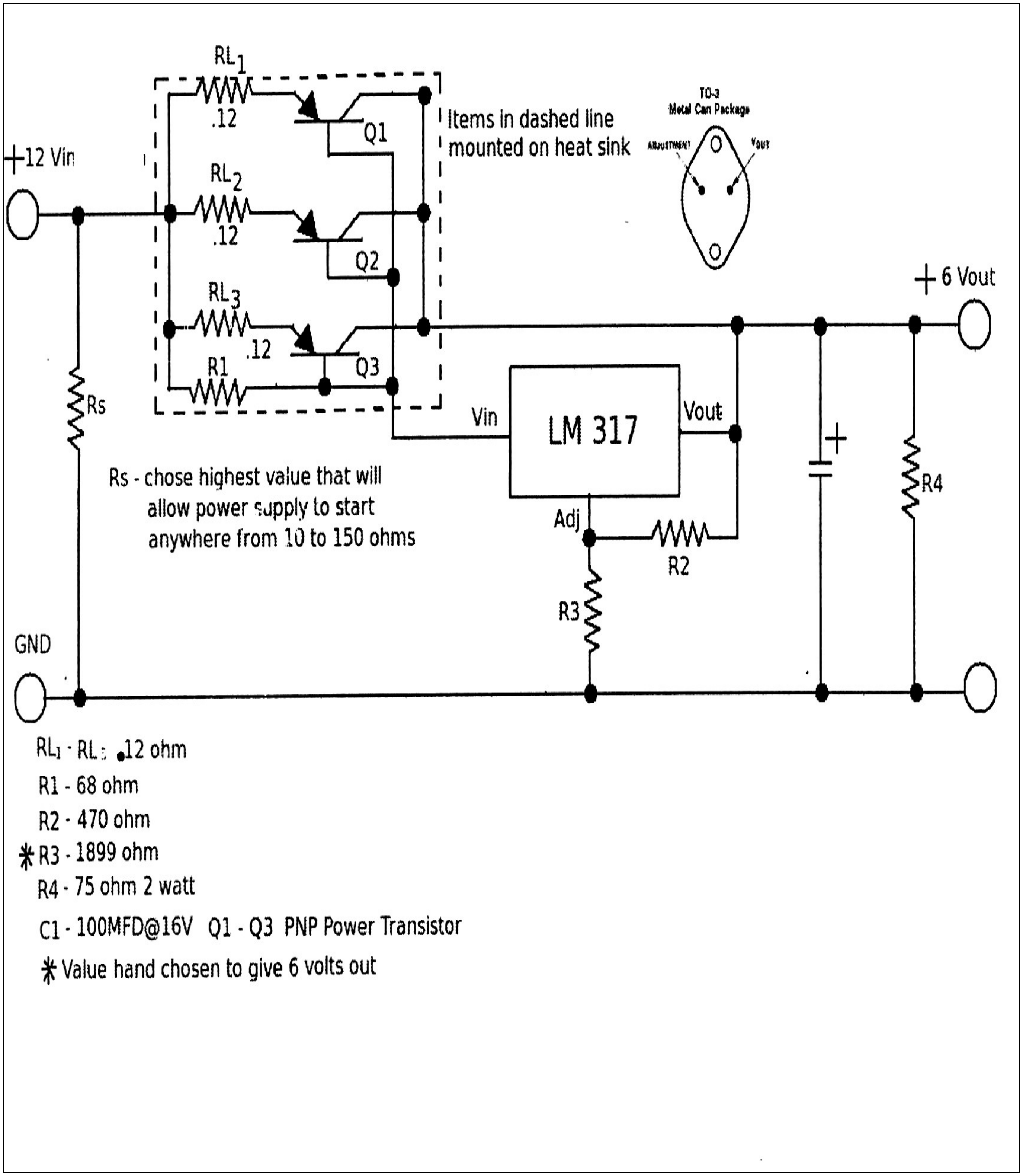
Credits:
"The Use of Minerals As Radio Detectors" from The American Minerologist, August 1922

"Radio-Detector Minerals" from The American Minerologist, August 1925

"Pre-1900 Semiconductor Research and Semiconductor Device Applications" by Asif Islam Khan, Bangladesh University of Engineering and Technology

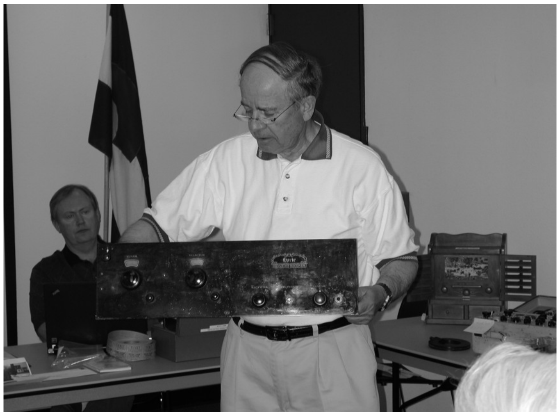
"Crystal and Solid Contact Detectors" by Alan E. Flowers, June 1909

"Crystal Clear" Volumes 1 and 2 by Maurice L. Sievers



This is the schematic of the power supply that Bill Harris demonstrated at the May meeting.

Photos from May 16th Meeting at the Phillip Miller Library in Castle Rock



Bill Dial with his 1925 Lyric Radio found on dBay

Bill Harris with his modified computer supply

Mark McKeown with his replica cw transmitter

Don Andrus with his 1918 Frequency meter

Tom Pouliot with his replica Bakelite panel

Tom Kelly with raffle tickets

The Open Trunk

Member submitted advertisements

WANTED: Buy/Sell/Trade: "Heavy Metal" communications gear, telegraph related items, vintage calculators & microphones.
Robert Baumann, (303) 988-2089
HQ180A@aol.com. (07/09)

REPAIR SERVICE:
Radio repairs for club members. Reasonable rates. Good references.
Call David Boyle
303-681-3258 11/09

For Sale: by Dave Boyle
All of the following Older "Classic" radio and TV repair instruments have been thoroughly refurbished, repaired as needed, and most calibrated as appropriate. Please Note: Don't be shy about negotiating on the prices, offers welcome!

1) Heathkit IG-52, TV Alignment Generator, with manual and new test leads. Like new. **$85.**
2) Heathkit O-12, 5" Oscilloscope, built by seller. VG **$60.**
3) Bench variable AC power supply for powering up and for repair of old radios, as shown at the January Club meeting. With full meters and controls, newly built. **$70.00**
4) HP 3200B VHF Oscillator, 10 MHz. to 500 MHz. Laboratory grade. Solid state, Free manual on Internet. VG. **$225.**
5) HP 608E/F VHF Oscillator, Tube Type, Top of the line and sought after these days, Complete with spare new (special) tubes and manual. Comes with optional (free) 'scope cart---a perfect match. VG. **$145.**
6) Superior Tube Tester, Model TD-55, small portable in carrying case with all literature. Like New **$35**.
7) RCA Model WA-44C, Audio G, Generator, Sine and Square Wave. VG. $**38**.
8) Precision Apparatus Co (PACO) Model E-400 Sweep and AM, FM, and TV Signal Generator. Refurbished, New test leads,
With Manual **$90**

9) Power Supply; "Power One" model CP418A, 24vdc at 7amps and 5vdc at 7 amps. commercial quality, VG **$55.**
10) 2—Zenith TransOceanics
 # H500, Both completely refurbished inside and out. Repaired as needed and aligned. Both work great.
$95.00 OBO ea
Call
David Boyle, 303-681-3258 3/10

WANTED: Old microphones (not CB or ham), working or not.
Also, NBC chimes in good condition.
Tom Keeton 303-797-8073
11/09

FOR SALE: At a most reasonable price: Tektronix o'scope model 7704 (works) with cart, manuals, probes. Freq. resp. is 150 mhz
Call Barney Wooters
303 770-5314 11/09

WANTED: An AK 82, 90 or 92 chassis / speaker for an empty cabinet I have. **Contact Mike Cook.**
mldcook@hotmail.com
01/10

WANTED: Knobs from the 20's and 30's made in one piece (Black bakelite?) with a 0-100 scale commonly used on homebrew equipment.

Mark McKeown 303-278-3908
mmckeown@hughes.net 5/10

FOR SALE: Tube tester, Hickok model 533A w/supplements for European types
Electrical condition - very good, the unit is fully functional
Cosmetic condition - fair, some of the fabric covering is torn
I'll deliver the unit to Castle Rock.
Price is $125. Pete Rawson
719 687 7144 5/10

SUBMISSION OF ARTICLES AND ADVERTISEMENTS

Classified Ads for The Open Trunk and articles of any radio/electronic or historical related subject to be published in the Flash are encouraged and welcomed. The article(s) should be submitted in Microsoft Word, RTF, or as text cut/paste into your email to Steve Touzalin, either by email at stevetou@comcast.net , or by postal mail to 417 So. Queen Circle, Lakewood CO 80226 .

Formatting is not necessary, but if you do, set the font to Times New Roman, size 10, left justified. If you have graphics (.jpg files) to be inserted, please name them and be specific about how you would like them placed. We will do our best based on space limitations.

The July 11th, 1:00 pm meeting will be at the Philip Miller Public Library in Castle Rock

Directions

From I-25: Take the Plum Creek Parkway, exit #181
Turn East onto Plum Creek Parkway.
Turn Left (North) onto S. Wilcox Street and continue north 2 tenths of a mile.
The Philip S. Miller Library is on the east side of the street at 100 S. Wilcox St.
The building is towards the back of the parking lot, past the Dairy Queen.

Colorado Radio Collectors
Antique Radio Club
417 S. Queen Cir.
Lakewood CO 80226

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