

Working With Crystal Control: A 'Part 15' Broadcast Band Transmitter

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The first continuous-wave sources of radio frequency power were AC generators; in 1907, a Swedish engineer named Ernst Alexanderson designed a large alternator that could generate 100 kHz at about 20,000 rpm. By 1911, DeForest's crude Audions were being used as amplifiers, and it's a safe bet that very soon after that, someone ran into the unwritten rule: if you want to design an oscillator, build an amplifier.

There's evidence that several inventors, Lee DeForest and a Russian named Popov among them, were observing tube oscillations and trying to understand them. But it was Edwin Armstrong who applied for the first patent for a vacuum tube oscillator in 1913 while he was still a college student. DeForest won a patent suit later, even though he apparently never fully understood the way his own tubes operated.

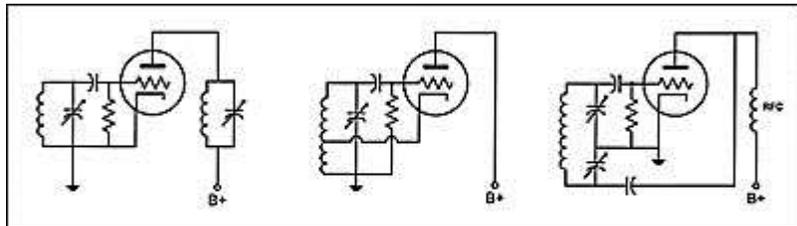


Fig. 1. Three basic triode oscillators. From left: Armstrong Tuned Plate-Tuned Grid, Hartley, Colpitts.

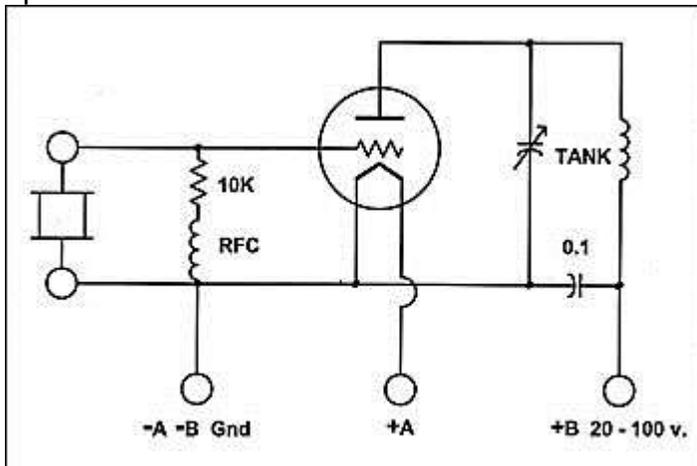
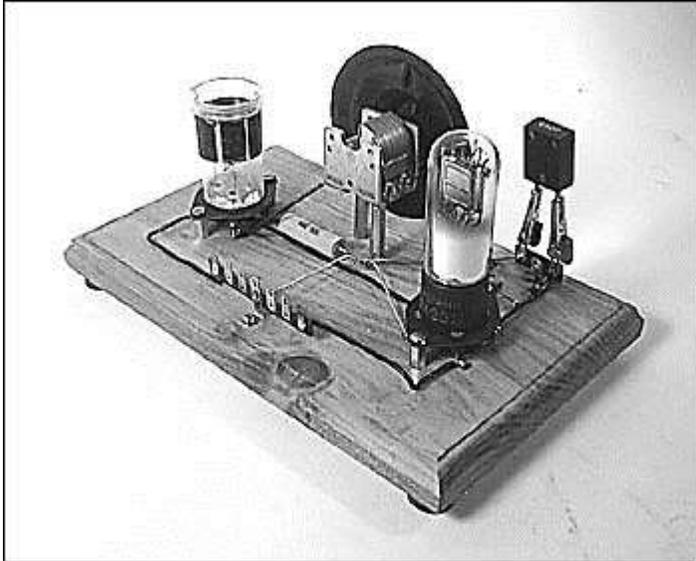


Fig. 2. Circuit of crystal test unit. See text for tank circuit values.

Armstrong's oscillators used coupled inductors in plate and grid circuits. By 1915 two more American inventors -- W.E. Hartley and Edwin H. Colpitts -- had patented variations in triode oscillators using single-inductor resonant tanks and capacitance coupling. Figure 1 shows simplified schematics of the three types of oscillators. It's easy to breadboard these simple circuits, but they all share one unpleasant characteristic. They drift around

in frequency with supply voltage changes, parts temperatures, and maybe even the mood of the operator!



The breadboarded crystal test unit.

Figure 3 is the schematic of the transmitter--a crystal-controlled design using a 6BE6 modulated by a 6AK5 speech amplifier. It's basically a development of a standard phono oscillator circuit. I chose the RF parts to allow the transmitter to operate at 1690 kHz. The coil is the same one used in the breadboard test circuit; the capacitor is a 300 pF mica trimmer set at about 150 pF.

To avoid running afoul of FCC emission rules for unlicensed operation, as stated in Part 15 of Title 97 (1, 2), the output of

this thing has to be limited. The input power to the final stage, the 6BE6, must not exceed 0.1 watt; the antenna can't be more than 3 meters in length.

Looking at the schematic, you'll see that the power supply is line-isolated. I used a Stancor P-6375 transformer rated at 6 volts, 2 amps to light the tube heaters and make 120 volts of B plus. Any transformer with split 120-volt primaries can be used this way; you use one of the primaries as an isolated secondary, keeping the load power at half the transformer's rating to be safe.

The 6AK5 gives a voltage gain of almost 50, so that a crystal mic will give nearly 100% modulation of the carrier. There is about 10 volts of RF across the 1690 Kc crystal, and at the plate of the 6BE6 there can be as much as 100 volts of modulated carrier. You adjust the tank capacitor with the antenna plugged in.

Shunt feed to the output tank keeps DC off the antenna. The resistor marked "R legal" is of a value that keeps the 6BE6 plate current starved enough to meet the 100-milliwatt power limit, and the 10-foot antenna lead is plenty long enough to get across the distance between the kids' houses. The antenna is made of three coat hangers soldered together with a banana plug at the feed end. The "key" is a pushbutton on the front panel.



The completed broadcast band transmitter. See text for tank circuit values.

I made the chassis for this from pieces of copperclad - my material of choice. When finished, I soldered in a bottom plate to keep curious fingers out.

After I built this "breadboard," I fired it up into the ten-foot wire and drove around my palatial country estate in a golf cart with a portable radio to see how far the signal would carry. It was pretty much gone 600 yards down the hill to our main road. With a pair of good receiving antennas, the kids will be able to hear each other just fine across their 300-yard distance.

By the way, this circuit makes a nice little radio station for your home. Short out the key, feed in a tape of some old-time radio programs, and you can tune in the show on all the old radios in your collection (They do all work, don't they?).

References

(1) "Understanding Range Limitations for Low-Frequency Unlicensed Transmissions" by Tom Warnagris, *RF Design* magazine, April, 1999

(2) FCC Part 15 Discussion, ARRL Web site; <http://www.arrl.org/tis/info/part15.html#Technical>

(3) *A Chronology of Communication Events Part 2: 1900 to Present*
http://people.deas.harvard.edu/~jones/history/comm_chron2.html

Notes On Development of Crystal Control

After the Curies, the first application of the piezoelectric effect was made by Prof. P. Langevin in France in 1917. Langevin used X-cut plates of quartz to generate and detect sound waves in water. His object was to provide a means for detecting submarines and his work led to the development of SONAR and to the science of ultrasonics, the results of which are still making headlines (viz., the recent announcement of the successful use of ultrasonic imaging in mammography).

Langevin's work stimulated others to investigate the phenomenon of resonance in piezoelectric crystals. Among those who became interested were A.M. Nicholson of the Bell Telephone Laboratories and Prof. W. G. Cady at Wesleyan University. Both men, working with Rochelle salt, observed the reaction of the resonant piezoid on the driving circuit and both applied for patents based upon their observations. Subsequent litigation resulted in a legal decision in favor of Nicholson who is therefore considered to be the inventor of the piezoelectric oscillator.

In 1919 Cady used a quartz piezoid to control the frequency of an oscillator and in a series of papers during the next three years he described the use of quartz bars and plates as frequency standards and wave filters. It is generally accepted that Cady was the first to use a quartz piezoid to control the frequency of an oscillator circuit.

Both Nicholson and Cady used devices which would today be called monolithic resonators, having two sets of electrodes on the same crystal. It remained for Prof. G. W. Pierce of Harvard University to show, in 1923, that a quartz plate with only one set of electrodes could be made to control the frequency of an oscillator circuit using only one vacuum tube. Pierce's circuit has probably been used more than any other quartz crystal oscillator circuit.

In 1924 A.T.& T.'s station WEAf in New York City became the first in the United States to control its frequency with a quartz crystal unit (*Note: see p.23 for an illustration of the WEAf transmitter and also p.25 for a mention of crystal control at station KMMJ in the 1930s-ed.*) Within a few years all radio stations went to crystal control, thus providing

another market for quartz crystal units.