Crystals are *EVERYWHERE* !

September 2010

FRRL Program

AH6EZ

Tire Pressure Guage
Washing Machines
Motorcycles
Crystal Filters
RC Toys
Cash Registers
Desktop Computers
Printers
Irons
Garage Door Openers
Police Radar
PS2
GPS Receiver
Stereos
Televisions
Satellites
Every Ham Radio
Smoke Detectors
Phono Pickups

Crystals are *EVERYWHERE* !

Water Softeners
Cameras
Vintage Transmitters
Space Ships
Test Equipment
Xbox
Laptop Computers
Cell Phones
Weather Thermometers
Calculators
MP3 Player
Appliances
Tools
Stop Lights
Answering Machines
Watches
Door Bells
Coffee Pots
Thermostats
Clocks
Vehicles
Musical Greeting Card
Vehicles
Dryers
Tooth Brushes
Thumb Drives
Microphones
Bread Maker

History of Piezoelectricity

- First experiment in 1880 by Pierre and Jacques Curie
- Measurement of surface charges appearing on specially prepared crystals under mechanican stress
  - Tourmaline, Quartz, Topaz, Cane Sugar, Rochelle Salt
- Curies did not predict crystals exhibiting stress (oscillation) in response to applied electric field
- Mathematically deduced from thermodynamic principles by Lippmann in 1881
- Curies immediately confirmed existence of the "converse effect," and complete reversibility of electro-elasto-mechanical deformations in piezoelectric crystals.

First Practical use of crystals

- First practical work on piezoelectric devices during WWI
- Langevin perfected ultrasonic submarine detector in 1917
- Transducer was thin quartz crystal mozaic glued between two steel plates (resonant frequency of about 50 KHz)
- Mounted in submersible housing
- High frequency underwater "chirp" underwater measured depth by timing return echo

1920-1940 Progress

- Megacycle quartz resonators developed as frequency stabilizers for vacuum-tube oscillators, 10X stability increase
- Material testing methods based on propagation of ultrasonic waves
  - Elastic and viscous properties of liquids and gases could be easily measured
  - Invisible flaws in solid metal structural members could be detected
  - Acoustic holographic techniques were successfully demonstrated
- Transient pressure measurement
  - Study of explosives and internal combustion engines
  - Other previously unmeasurable vibrations, accelerations, and impacts
- Classic piezoelectric applications conceived and developed
  - microphones, accelerometers, ultrasonic transducers, bender element actuators, phonograph pick-ups, signal filters, etc.
  - Available materials often limited device performance

Ham Radio Crystals

- First RF oscillator in 1921 by Dr. Cady
- 1923 first commercial crystals
- Amateur radio is the first market for crystals
- Lots of experimentation to get higher power and not damage the crystal
- Aug 1925 QST, General Radio Co. offers quartz crystals finished to specified frequency $50[$633], unfinished, untested blanks offered by A. Espositer $4 [$50]
- Nov 1925 QST J.M. Clayton gives detailed instructions on cutting plates from raw quartz crystal, finishing plates to wavelength, mounting finished resonator
- 1926 WEAF, NY is 1st commercial broadcast station to use crystal control
- 1934 Bell System Tech Journal, zero temperature coefficient cut called AT-cut
- Nov 1934 QST Bliley Electric Co, PA, makes AT cut crystals for hams
- 1936 Ham radio crystal control TX described as the rule rather than the exception

Crystal Controlled Transmitter Development

- Practical development on crystal controlled transmitters largely done by amateur radio
- Why crystal control of transmitters in particular? And further, why were transmitters first?
- Typical tank circuits before crystal control were simple, the antenna was part of the tank circuit.
- When the antenna moved in the wind, the output frequency would change.
- Typical transmitters were one tube oscillators with antenna as part of tank circuit.
- Simply constructed LC tank circuit, frequency changed frequency significantly with temperature.

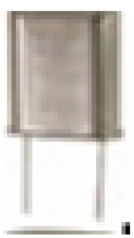
- Amateur radio operators in the teens, twenties and into the 1930s built most of their equipment.
- They also built a number of the parts they used.
- Practical side to building their own parts was lack of radio stores in much of U.S.
- Finished quartz crystal plates were also very expensive.
- General Radio offered crystals for $35 ($443 today) in 1925 finished to an approximate frequency
- $50 ($633 today) finished to an exact frequency specified by the purchaser.

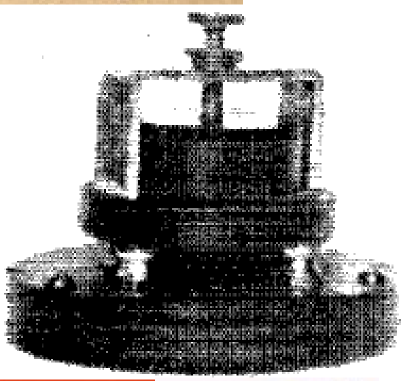
- Cut a plate out of faceted crystal using carborundum powder on back of hacksaw
- Finished on piece of plate glass with carborundum powder

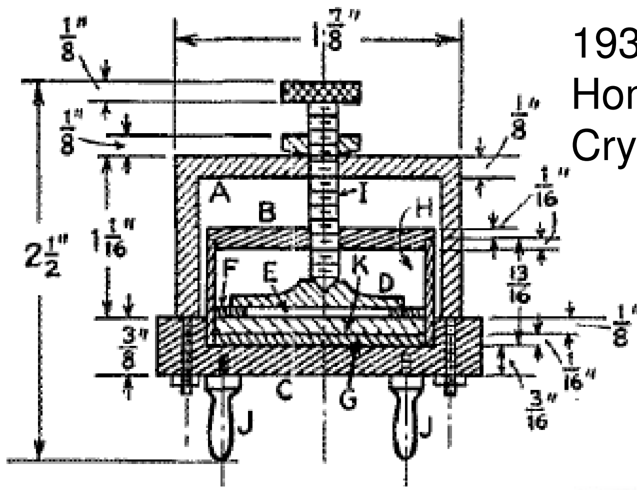
- In the mid and late-1920s, most purchased crystal resonators did not come with holders
- Holders could be purchased for an additional cost or could be made at home.
- Home cut resonators typically went into home made holders.

Grinding your own crystal

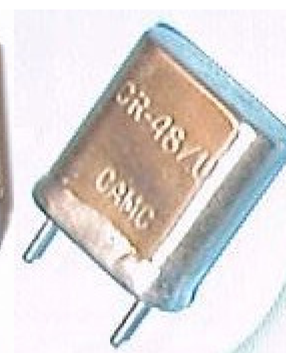
- Smaller crystal oscillates at higher frequency
- Real hams start with a raw quartz crystal
- If you find a box of crystals just below a band, you are in business
- As a novice I started at 6.77 MHz
- Keeping the sides of the crystal parallel is critical
- Ajax slurry and then toothpaste on plate glass
- # of figure 8s on two corners, then same # on other 2 corners
- Dry off and reassemble and test
- If it stops oscillating, or is chirpy, try grinding in the center on each side
- You can also try beveling the edges equally (also raises the frequency)
- Try to be consistent with pressure and Ajax slurry
- With practice, you can predict the frequency change with # of figure 8s
- If you go to high in frequency, you might try pencil lead to lower it
- There used to be an SSB net on 7.255, I ended up with a lot at 7.256
- That was not good when I had a DX40 on AM…

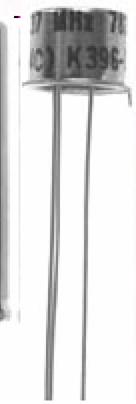




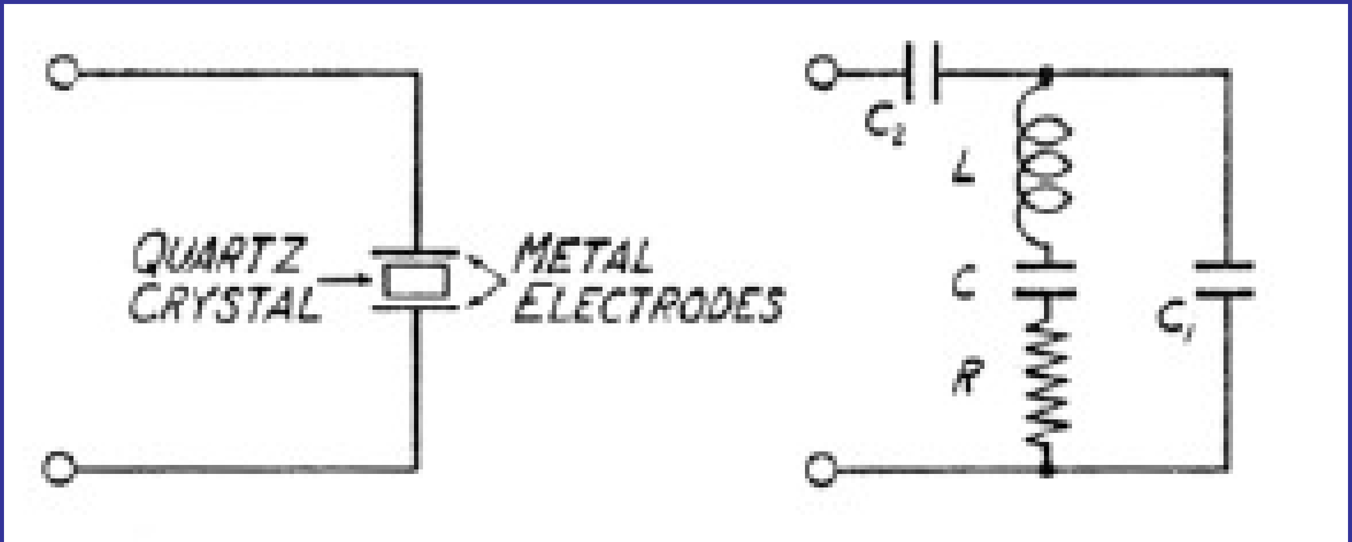


1930
Homebrew
Crystal Holder





Electrical equivalent of a crystal



L = Crystal mass = .1 to 100s of Henrys

Since X_L is very large, the Q or selectivity is very high (6000-30000) Q = (2*pi*F*L)/R

C = resilience of the crystal

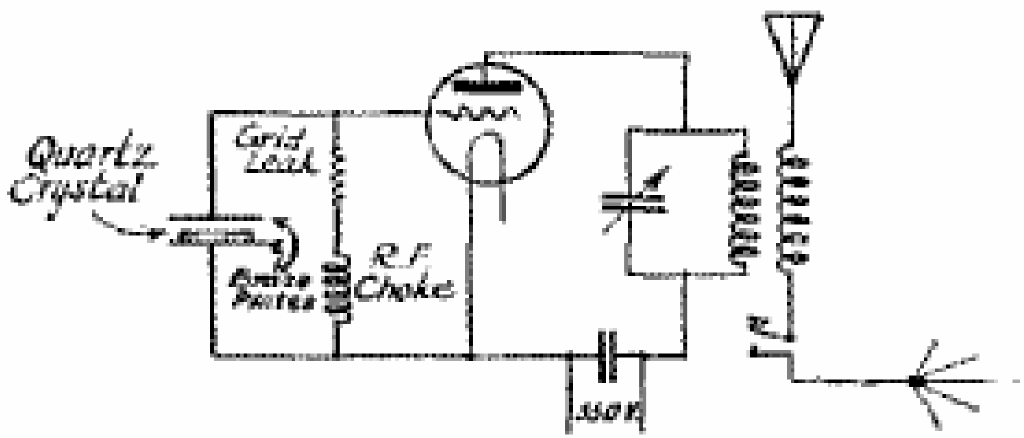
R = frictional resistance losses

C_1 = capacitance of metal electrodes with crystal as a dielectric

C_2 = capacitance of electrodes if not touching the crystal

Can you imagine a transmitter that never shifts its wave even a hundredth of a meter? Can you imagine making a schedule for 96.38 meters and knowing that you will be right on that wave and know that the other man will be tuned right to you? And can you imagine getting from the receiving operator a report that during hours of operation the beat note in his phones never changed even a particle? These things are possible with the oscillating crystal.—Technical Editor.

July 1924 QST



Circuit used at 1XAU for operation with 5-watt tubes

FIG 5

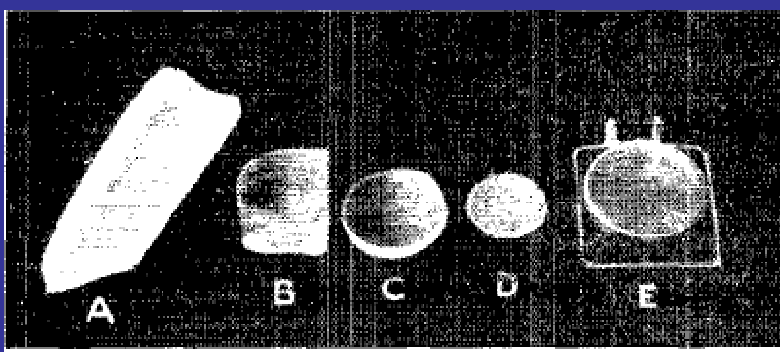


Fig. 3. Stages in the Finishing of a Quartz Crystal. A—Rough Crystal; B—Oscillator B.ank; C—Low Frequency Oscillator; D—High Frequency Oscillator; E—Mounted Crystal.

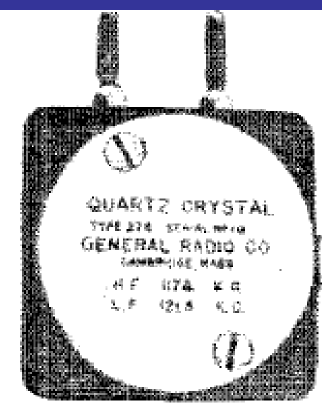


Fig. 2—A Mounted Crystal

May
1931
QST

The Romeike Crystal Oscillator

A Method of Controlling the Frequency of a High-Power Oscillator With a Low-Power Tube

By Marshall P. Wilder, D4CJ-W1AWK* and Rudolf Romeike, D4AU**

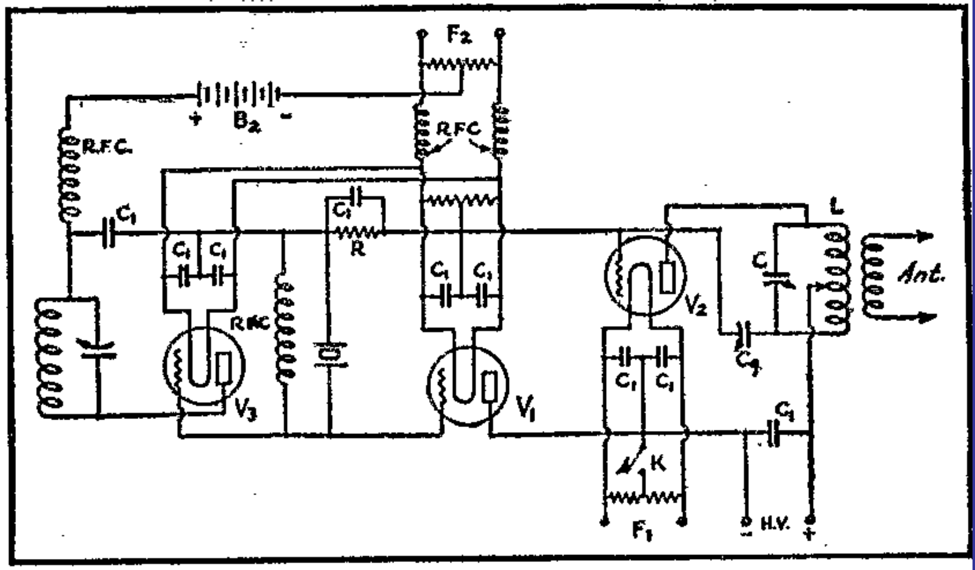


FIG 3.—AN ADDITIONAL TUBE IS NECESSARY FOR SATISFACTORY KEYING

The tube V_1 is connected as a grid-leak for V_2 and has a quartz crystal in its grid circuit. With the crystal removed from the circuit, the grid condenser C_g is adjusted so that the circuit of V_2 is regenerative but not self-oscillating. When the crystal is inserted and the L-C circuit is tuned to the crystal frequency, oscillation at this frequency results. Excessive regeneration must be avoided to obtain stability and to prevent over-excitation of the crystal circuit with the possibility of shattering the crystal.

March 1935 QST, W5ARV

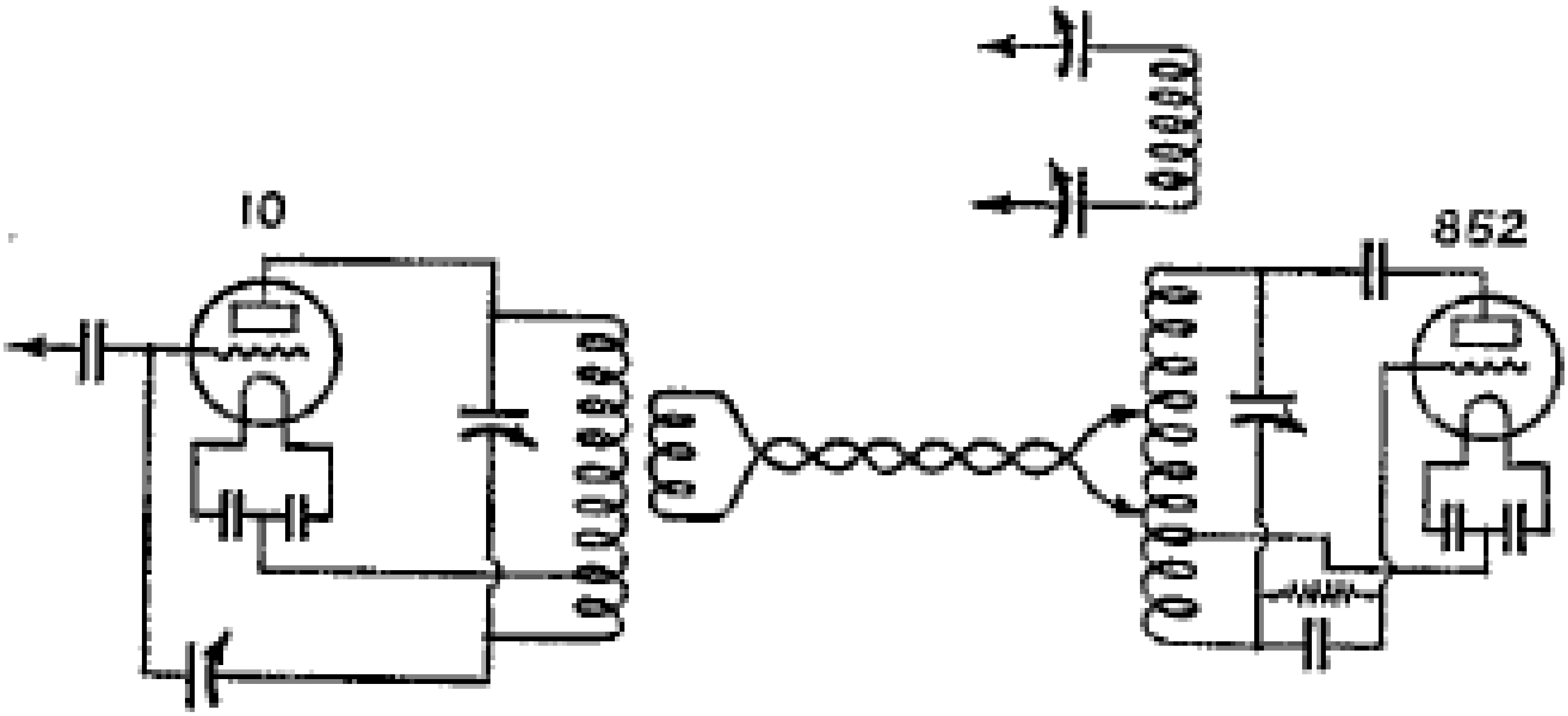


FIG. 2—CRYSTAL-LOCKED HARTLEY OSCILLATOR

280 watts input

The 6L6 Beam Power Tube as a High-Output Crystal Oscillator

By Frank W. Edmonds,* W2DIY

June 1936
200 watts

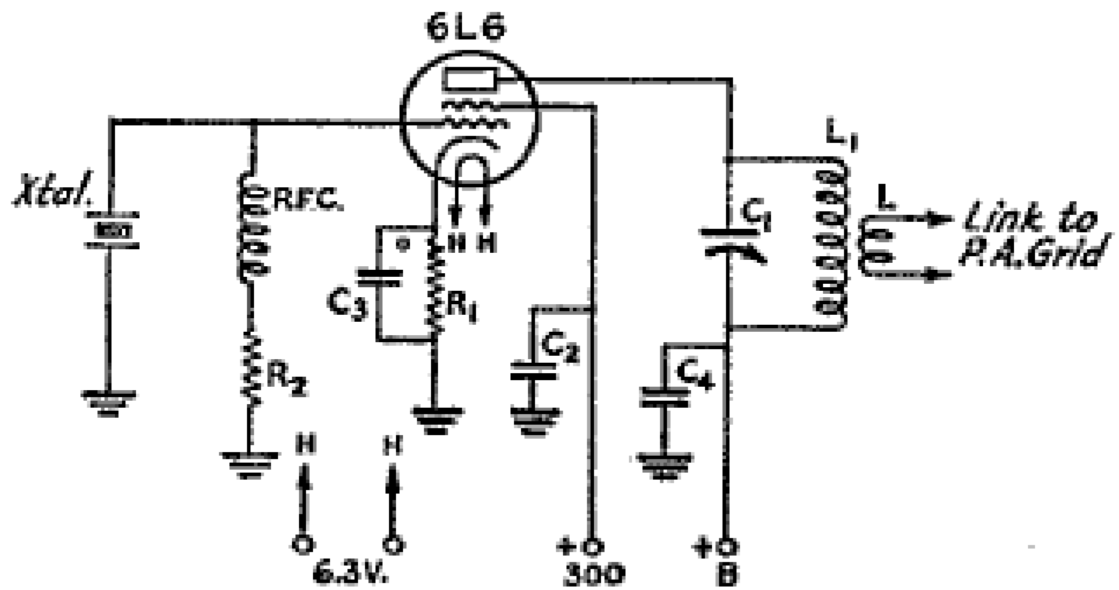


FIG. 1—CIRCUIT OF THE EXPERIMENTAL 6L6 CRYSTAL OSCILLATOR

L_1—Usual coil to suit the crystal frequency.
C_1—100 μμfd.
C_2, C_3, C_4—0.1 μfd.
R_1—400 ohms.
R_2—10,000 ohms.

The 807 as a Crystal Oscillator

By John Stiles,* W8PNL

January
1937
40 watts input

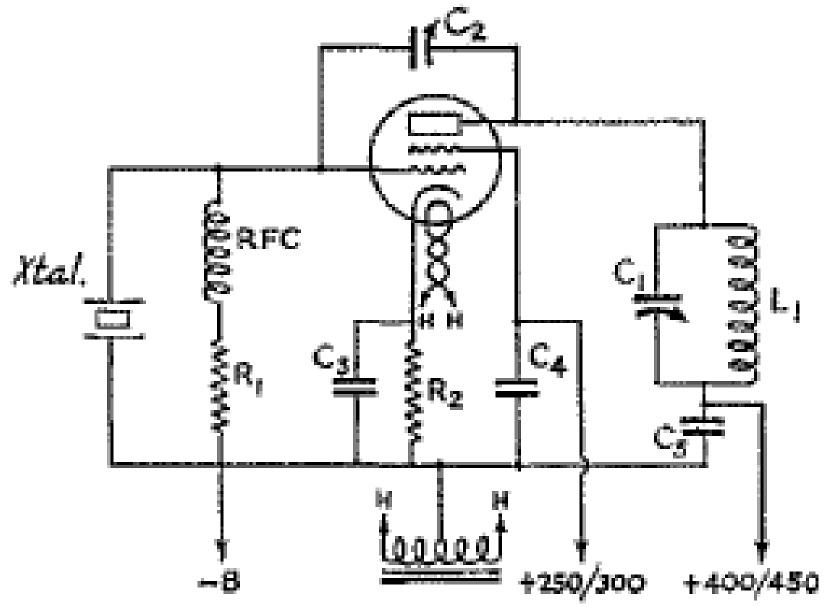


FIG. 1—CIRCUIT OF THE 807 OSCILLATOR

C_1—100-μμfd. variable.
C_2—6 to 8 inches of all-rubber lamp cord, pulled apart to give optimum capacity.
C_3, C_4, C_5—0.01 μfd., 500-volt.
R_1—13,000 ohms, 2 watt.
R_2—400 ohms, 10 watt.
RFC—Short-wave choke.
L_1—30 turns No. 12 enamelled, turns spaced diameter of wire; coil diameter 2¼ inches. Wound on celluloid strips cemented with Duco cement.

May 1938 QST
Oscillator for testing grinding of crystals

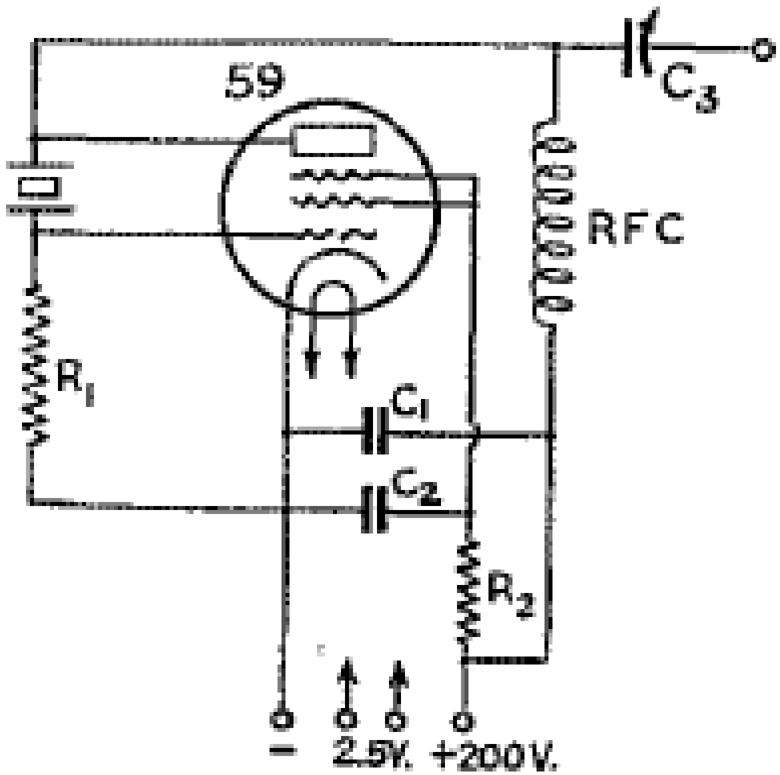


FIG. 1—CIRCUIT OF THE FIXED-TUNED CRYSTAL OSCILLATOR

January 1940 QST by W8CSE

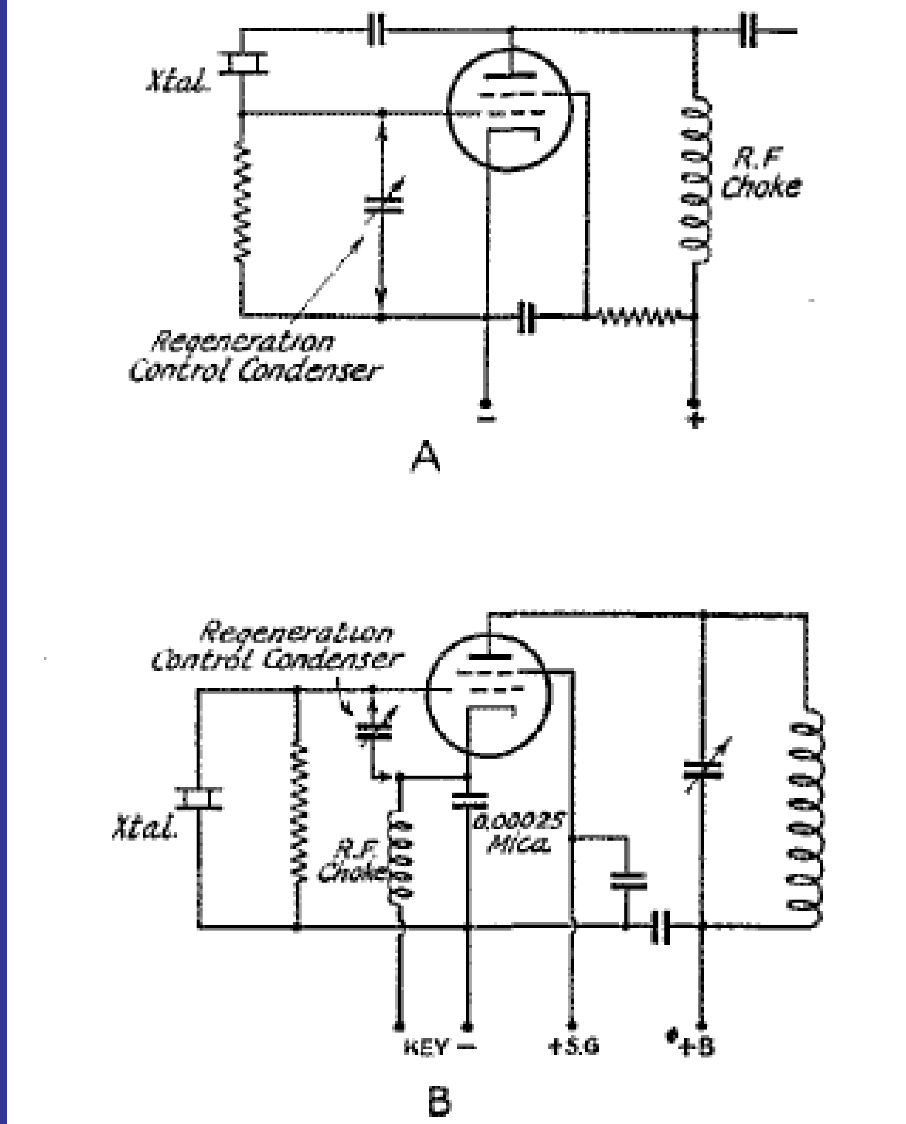


Fig. 3 — Circuits for introducing regeneration in Pierce and gridplate oscillators to help operation with stubborn crystals.

Transition from crystals to ceramics – 1940-1965

- Piezoceramics using Barium titanate and Lead Zirconate Titanate
- Doping with metallic impurities for dielectric constant, stiffness, piezoelectric coupling coefficients,
- Tailoring a material to a specific application

- Powerful sonar - new transducer geometries (such as spheres and cylinders) and sizes achieved with ceramic casting
- Ceramic phono cartridge - cheap, high signal elements simplified circuit design.
- Piezo ignition systems - single cylinder engine ignition systems which generated spark voltages by compressing a ceramic "pill".
- Sonobouy - sensitive hydrophone listening/radio transmitting bouys for monitoring ocean vessel movement.
- Small, sensitive microphones
- Ceramic audio tone transducer
- Snap action relays

Crystal Manufacturers

Aircon Manufacturing Corp. (Kansas City, MO)
Aircraft Accessories Corporation (Kansas City)
American Crystal Co. (Kansas City, MO)
ARC (Aircraft Radio Corp.)
August E. Miller CO. (Bergen, NJ)
Bangor ELEC IND
Beaumont Electric (Chicago, IL)
Bellefonte Radio Eng. & Mfg. Co. (Bellefonte, PA)
BES Company
Blilely Electric Co. (Erie, PA)
Bliley Mfg. Co.
BMS Company
Bodnar Labs
Bond Quartz Crystal
Bud Company
Cal Crystal Lab Inc. (Anaheim, CA)
Bomar Crystal Co. (Middlesex, NJ) #
Cambridge Thermionic (Cambridge, MA)
Carlisle Crystal Co.
Cathodeon Crystals Ltd. (Linton, England)
Cecor (Kansas City, MO)
CB-VJ COmpany
Colorado Crystal Corp. (Loveland, CO)
Commercial Crystal Co. (Lancaster, PA)
C.R. Snelgrove Company, Toronto, Canada
Crystal Labs (Wichita, KS)
Crystal Networks Products Corp.
Crystal Products/Whitehall Electronics
Crystal Products (Kansas City, MO)
Crystal Research Lab (Hartford, CT)
Crystal Research Laboratories a.k.a. CRYSTALAB
The Crystal Shop (Barney, VT)
Crystalonics
Crystek Crystals (Ft. Myers, FL)
C.T.& E. Div., G.A.I. Inc.
CW Crystals (Marshfield, MO)
CW Manufacturing, Los Angeles, CA
Daughetee Mfg. Company
Denver Crystals
Downing Crystal Corp.
Duart Manufacturing Co. (San Francisco, CA)
DX Xtal (Chicago, IL)
E.B. Lewis Company
ECCO Crystals
Eidson Electronic Co. (Temple, TX)
EICO (Brooklyn, NY)
Elec. Prod. (Oakland, CA)
E.P. Co.
Faberadio
F.E. Co.
Federal Telegraph and Radio Corp. (Newark NJ)
Federal Telephone Co.(Newark, NJ)
F.M.S. Labs (Kansas City, MO)
Franklin Engineering Co.
Frequency Management Inc. (Huntington Beach, CA)
G.E.C. (England)
General Electric Company
General Radio, Cambridge, MA
General Radiotelephone (Burbank, CA)
Gentleman Products (Omaha, NE)
Good-all Elect. Manufacturing Company
Gross Radio
H.L. Inc.
Hallicrafters Company
Harvey Radio (Cambridge, MA)
Harvey Wells (Southbridge, MA)
Hatcher Fisk Manufacturing (Topeka, KS)
Henry Manufacturing
Henry Radio Co. Los Angeles, CA
Higgins Industries
HiPower Crystal Co. (Chicago, IL)
Howard Moldings (Crystal cases) (Kansas City, MO)
Hundley Crystal Co. (Kansas City, KS)
Hunt Corporation
ICM, International Crystal Manufacturing (Oklahoma City, OK)#
JAN Crystals (Ft. Myers, FL) #
James Knight (JK) Crystals (Sandwich, IL)
Jet Crystals (Torrance, CA)
John Meck (Plymouth, IN)
Johnson
Kemlite Lab.
Keystone Electronics
Keystone Piezo
Kinsekisha (KSS) - (Japan)
Lafayette
Leeds Radio (New York City, NY)
Les Smith (Lesmith) LTD. (Oakville, ONT)
Link Radio
Majestic Radio (Chicago, IL)
Mac's Radio Crystals (South Gate, CA)
Marden Crystals
Master Crystal Labs (Los Angeles, CA)
McCoy Electronics Company
MID Mfg. (Kansas City, MO)
Mill Laboratories
August E. Miller Company, (North Bergen, NJ)
Mission Bell Radio Manufacturing Co. Inc. (Los Angeles, CA)
Monitor Co. (Pasadena, CA)
Monwatt Electric Corp.
Motorola (Chicago, IL)
MP Company
National Scientific Products Co.
North American Phillips
Northern Engineering Laboratories (Burlington, WI)
Northern Radio Company
Pacific Radio Crystal Co. (San Francisco, CA)
PAN-EL LABS INC.
Pan Electronics (Atlanta, GA)
Peterson Radio Co. a.k.a. PR Crystals (Council Bluffs, IA)
Phillips
Piezo Technology, Inc.
Polytech Devices
PR Crystals (See Peterson Radio Co.) #
Precise Development Company (Chicago, IL)
Precision Apparatus Co. (Elmhurst, NY)
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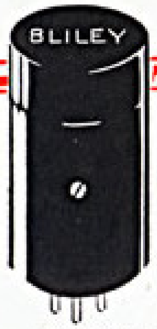
Quartz Lab Inc. (Kansas City, MO)
Quartz Products Co. of New York
R9 Crystals
RADCO CBYN (Kansas City, MO)
Radell Co. (Indianapolis, IN)
Radio Specialty Manufacturing Co. (Portland, OR)
Radiomarine Corporation (New York, NY)
Ray Jefferson Inc. (Freeport, NY)
RCA - Victor Div. (Camden, NJ)
Reeves Hoffman Corp. Carlisle, PA
Reeves Sound Labs
R.E.L. (New York City)
Research and Dev. Co. (Kansas City, MO)
Rex Bassett Inc. (Ft. Lauderdale, FL)
RIJOR PRODUCTS CO. (New York)
Ross Manufacturing
Savoy Crystals
S.C. Company
Scientific Radio Products *
Sentry Crystals (Portland, OR)
Sentry Crystals (Chickasha, OK)
Sherold Crystals (Kansas City, KS)
Sickles Co.
Silver City Crystal Company
Silver City Glass Co.
Singer Metrics
Sipp-Eastwood Co.
C.R. Snelgrove Co, Toronto, Canada
Somerset Labs
Standard Coil Products
Standard Crystal Co.
Standard Crystal Corp.
Standard Piezo (Carlisle, PA)
STD
Sun Parts Distributors(Washington, DC)
Sunset Crystals
Tedford Labs
Telicon
Texas Crystals (Ft. Myers, FL)
Texas Crystals (River Grove)
Texas Crystals (Los Angeles, CA)
TOYO
Trigger Electronics
Tru Lite
TRW COrp.
Turner Co. (Cedar Rapids, IA)
Union Piezoelectric Co.
Universal Television (Kansas City, MO)
U.P Company
U.S. Crystals Inc. (Los Angeles, CA)
Valpey (Hollston, MA)
Wenkstern Hasley Co. (Cedar Rapids, IA)
West Crystals - Canada
Western Electric
Westline Xtal Co. (West Los Angeles, CA)
White Equipment Company (Indianapolis, IN)
Whitehall Electronics (Los Angeles, CA)
William T. Wallace Mfg. Co. (Peru, IN)
Wonder Lite Co. (West Orange, NJ)
World Radio Laboratories
Wright Co. (USA)
Wright Co. (Canada)



BC6 Oven

BLILEY

Crystal Oven

A scientifically designed constant-temperature oven, neat in appearance, weighs only 6 oz., holds within one degree C., plugs into standard 5-prong socket, heats quickly. Rating: 7.5V., ¾A. For inch sq. 80, or 160M crystals. Interchangeable plug-in with standard Bliley holders. Type BC6, each. **$7.50**

Bliley Oven Mounted X-cut Crystals - Type BC7

Mc Band	*Supplied within*	*Precision*	*Freq. held within approx.*	*Price*
1.7, 3.5, 7	*10Kc*	*0.03%*	*1.7Mc-50c*	*$11.30*
1.7, 3.5, 7	*1Kc*	*0.03%*	*3.5Mc-100c*	*14.00*
1.7, 3.5, 7	*Exact F.*	*0.03%*	*7Mc-200c*	*16.00*
100Kc Std. F.	*Exact*	*0.05%**	*1 cycle*	*16.50*

**Adjustment by purchaser will greatly reduce this.*

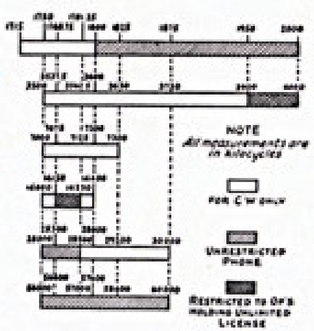
CHOOSE

BLILEY

THEN

CHOOSE YOUR

FREQUENCY



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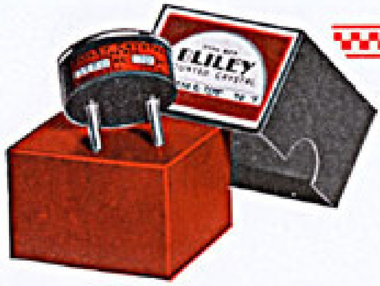
MANUFACTURED BY BLILEY ELECTRIC CO. ERIE, PA.

Bliley Crystals



BLILEY

Mounted Crystal

The BC3 mounted crystal banishes frequency worries. It is not only less expensive, completely mounted; but it insures positive satisfactory results. Simply plug in . . and you're set. It's the ideal crystal unit. Prices from **$3.95**

Outstanding Advantages—

- ***Powerful special size X-cut crystal.***
- ***Mounted in compact molded bakelite holder.***
- ***Locks transmitter on single frequency.***
- ***Accurate calibration—0.03%***
- ***Frequency marked on each name-plate.***
- ***Frequency drift under 23 cycles/million/°C.***
- ***Ideal for direct control of the RK20.***
- ***Plugs into 5-prong tube socket.***
- ***Quick delivery through your distributor.***
- ***Stock price only $3.95.***

BC3 MOUNTED CRYSTALS

Mc Band	*Supplied to specified freq. within*			
	10 Kc	*5 Kc*	*1 Kc*	*Exact F.*
7.0, 3.5	*$3.95*	*$4.90*	*$5.90*	*$7.50*
1.7	*4.80*	*5.80*	*6.80*	*8.40*

Bliley BC3-A Mounted Crystals

The BC3-A crystal unit was designed for the more exacting amateur or engineer who desires a high degree of frequency precision without necessarily resorting to oven equipment. The BC3-A unit incorporates a special cut crystal ("A" cut) having an unusually low frequency-temperature coefficient, approximately 4 cycles/million/°C. This crystal is electro-mechanically stronger, permitting a greater power capacity. BC3-A crystal units utilize the type BC3 molded holder. Frequency precision 0.03%.

Supplied in the 1.7 and 3.5 megacycle bands only. Within 20KC, ... **$9.00** within 5KC, $11.00; or to exact specified frequency, $14.00. Completely mounted. Instructions included with each unit.

Supplied to all other practical specifications from 300KC to 5000KC at reasonable prices.

Standard Frequency Crystals

BC5 Unit

A 100Kc standard is the ideal frequency meter. A snap of the switch and the amateur bands are instantaneously outlined and equally subdivided. Easily built, it offers the progressive amateur dependable accuracy. Only one tube necessary. Instructions furnished. Completely mounted—Type BC5 . . . . **$9.50**

Single Signal Filter

The finest S.S. receivers use BLILEY quartz filters. A precision product, scientifically designed and rigidly tested, it insures maximum efficiency. Supplied to within 5KC of 465, 500, or 525Kc. Completely mounted—Type SSF **$5.90**

BC3-SSF Unit

Bliley crystals are the preference of leading radio engineers and progressive radio amateurs. They are used by federal, state and municipal governments, broadcasting stations, airway stations, radio manufacturers, and other services. You, too, will find them best. And they actually cost less in the long run.

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