Letters to the Editor

May/June Issue of *QEX*

Hi Larry;

I really didn't know that giving the Editor of a publication I enjoy, a good poke in the ribs from time to time could enhance my reading pleasure so much!

Regarding the 2008 May/June issue, not bad but...

I see another construction article with limited construction information slithered in under the tent. The SCR Preselector article sucked me in pretty well until I realized that there was limited construction info available except the enclosure. Harrumph, I say!

The *real* Jewell is the DDS article by James Hagerty, WA1FFL. Now, that's worth a huzzah or two. I liked it so much that I bought the semi kit. I haven't received it yet but the spectral plots have me a bit excited.

N2ADR's Digital SSB Exciter is also a winner! Now, that's more like it. This guy is sharp.

— 73, Bob McCulla, K7HBG, 5025 E Pacific Coast Hwy, Suite P340, Long Beach, CA 90804; **k7hbg@arrl.net**

Hi Bob,

It's always good to hear from you. I appreciate hearing what you liked and what you didn't like in the May/June issue of *QEX*. Poke me in the ribs anytime you like!

I was pleased to have N2ADR write about his digital SSB exciter. He had that project on display at the ARRL/TAPR Digital Communications Conference last September. I talked to him about the project and asked him to consider writing about it. The VFO article by WA1FFL was also a very interesting article, I agree. Let me know how that kit works out for you.

I remain enthusiastic about the SCR Preselector. There may not be a lot of construction information, but the microprocessor code for the project, as well as the computer control program are available for free download, either from the author's Web site or from the *QEX* Web site, so I think it is buildable.

— 73, Larry Wolfgang, WR1B, QEX Editor; **lwolfgang@arrl.org**

Some Thougts on Crystal Parameter Measurement (Jul/Aug 2008)

Dear Editor, *QEX* Magazine,

Measuring quartz crystal parameters is one of those tasks that turns out to be much more complicated than it appears at first sight. The excellent article by VE5FP discusses some of the reasons for that, such as nonlinear effects (changes in crystal parameters with drive level) and issues associated with the measurement technique.[1]

There is, however, a more basic theoretical complication associated with the equations of the equivalent circuit model of a quartz crystal. People often speak of "series-resonant" frequency without specifying precisely what is meant by that term. There are at least three possible definitions. One is simply the series-resonant frequency of the motional inductance and capacitance, $f_{sm} = 1 / (2\pi \sqrt{(L_m C_m)})$, where L_m and C_m are the motional parameters. The other definitions are the frequency of minimum impedance, f_{sz}, and the frequency at which the impedance has zero phase (is purely resistive), $f_{s\phi}$.

It turns out that all three definitions of "series-resonant frequency" give different answers. It is not difficult (although tedious) to show that the standard crystal model (Figure 1) consisting of the series combination of L_m, C_m and R_m, all in parallel with the holder capacitance, C_0, gives:

$$f_{sz} = f_{sm} - \Delta$$
$$f_{s\phi} = f_{sm} + \Delta$$

where:

$$\Delta = f_{sm} (1 / 2Q^2) (C_0 / C_m)$$
$$Q = 2 \pi f_{sm} L_m / R_m$$

There are similar equations for parallel resonance:

$$f_{pm} = f_{sm} \sqrt{(1 + C_m / C_0)} \cong f_{sm} (1 + 0.5 C_m / C_0)$$
$$f_{pz} = f_{sm} + \Delta$$
$$f_{p\phi} = f_{sm} - \Delta$$

For many crystals, Δ is small enough that it can be ignored. In other crystals (especially overtone types), however, it can result in an error of several hundred Hz. For example, using estimated values for the crystal tested in the article (f_{sm} = 55.25 MHz, Q = 35500, C_0 = 4.5 pF, C_m = 0.00156 pF) gives Δ = 63 Hz.

The traditional crystal-impedance (C/I) meter is an oscillator with the crystal under test in the feedback path. (See Figure 2.) There is also a tuned circuit that is tuned to achieve zero phase across the crystal. The measurement uses the substitution method — a variable resistor may be switched in place of the crystal. When the tuned circuit and resistor are adjusted so that there is no change in amplitude or frequency when the resistor is substituted, then the resistor equals the equivalent series resistance, R_m, and the frequency of oscillation is the series-resonant frequency of zero phase, $f_{s\phi}$.

Most C/I meters also have provision for switching a capacitor in series with the crystal. The difference in frequency with and without the capacitor can be used to calculate L_m and C_m, given that C_0 and R_m are known. It is interesting to note that the series capacitor can also be used to measure the parallel-resonant frequency directly. It is easy to show that (ignoring the effect of R_m) the parallel-resonant frequency of a crystal with a capacitor in parallel is the same as the series-resonant frequency with the same capacitor in series.

The pi-network measurement circuit used in Jim Koehler's first measurement method is similar to the one outlined in an IEEE publication.[2] The main difference is his use of a low source and load impedance

[1]Notes appear on page 00.

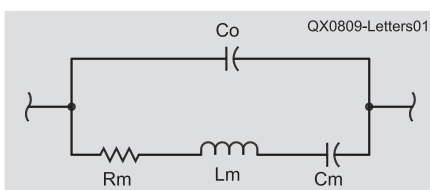

Figure 1 — Equivalent circuit for a quartz crystal.

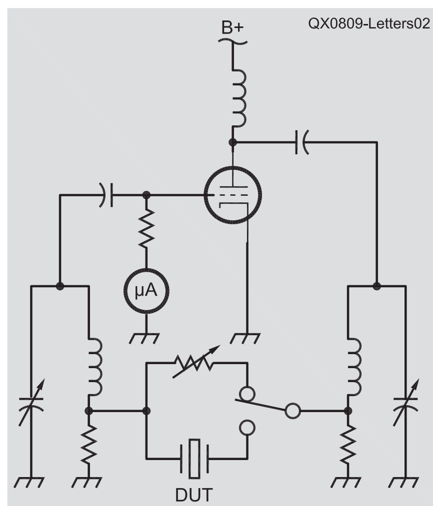

Figure 2 — Traditional crystal-impedance (C/I) meter.

instead of the 50 Ω usually used in the IEEE method. Compared to a C/I meter, this method has the advantage of a well-defined and adjustable drive level. It also allows measurements far from the resonant frequency to search for spurious resonances and to measure C_0, and is well-suited to automated testing. Several other key references on the subject of crystal testing are listed in Notes 3, 4, 5 and 6.

The frequency of maximum transmission of the pi-network circuit is not equal to any of the three previous definitions of series-resonant frequency! Based on an equation given in the IEEE publication listed in Note 2, the following correction factor may be derived:

$$f_\pi = f_{sm} - \Delta\,(1 + 4\,R_T / R_m)$$

where R_T is the source and load resistance (assumed equal) in the fixture. If R_T is much less than R_m, then f_π approaches f_{sz}, the frequency of minimum impedance, as expected.

The pi circuit in the article has $R_T = 25\ \Omega$. Again using the example crystal from the article (f_{sm} = 55.25 MHz, Δ = 63 Hz, R_m = 52 Ω) we get $f_\pi - f_{sm} = -185$ Hz. That is 185 + 63 = 248 Hz different from $f_{p\phi}$, as would be measured by a C/I meter.

In addition to the other sources of error mentioned in the article, the pi-network method has several issues associated with the fixture. Stray series inductance can be significant when low source and load impedances are used. I have measured values in the 100 to 150 nH range in a well-constructed fixture. Also, the source and load resistance can change as a function of frequency. For example, with a nominal 8.5 Ω dc resistance, I measured 9.5 Ω at 40 MHz. Finally, the stray holder capacitance of the fixture must be subtracted from the measured C_0 value.

Of course, all of this complexity can be avoided if the designer has access to a network analyzer or spectrum analyzer with tracking generator. Simply build a ladder filter with variable capacitors in shunt and in series with each crystal and then tune for the desired passband shape. (For tuning purposes, it is not necessary to observe the stopband.) I have had good luck building 4-pole filters using such a heuristic method. The trick is first to tune a pair of 2-pole filters separately, then connect them together and do final "tweaks" to get the desired response. When satisfied with the result, replace the variable capacitors with equivalent fixed values. Such a "design" technique is probably not suitable for commercial production, but is a reasonable solution for a one-of-a-kind home construction project.

— 73, Alan Bloom, N1AL, 1578 Los Alamos Rd, Santa Rosa, CA 95409; **n1al@arrl.net**

Dear Alan,

I appreciate your thoughtful comments and for pointing out several oversimplifications in my article. I intended the article to deal more with an algorithm for automatically making the *usual* measurements rather than a detailed discussion of the circuit itself. Your commentary is excellent, and should be read carefully by any student of the subject of crystal parameters.

— Regards, Jim Koehler, VE5FP, 2258 June Rd, Courtenay, BC V9J-1X9, CANADA; **jark@shaw.ca**

Notes

[1]Jim Koehler, VE5FP, "Some Thoughts on Crystal Parameter Measurement," *QEX*, Jul/Aug, 2008, pp 36-41.

[2]*Standard Definitions and Methods of Measurement for Piezoelectric Vibrators*, Publication # 177, Institute of Electrical and Electronics Engineers, N. Y. 1966. The equation cited is equation 10b in Table 5, with b = 1 (no shunt inductor). Applying McLaurin's series, eliminating small terms, and substituting for reactance results in the equation for f_π.

[3]*Basic Method for the Measurement of Resonance Frequencies and Equivalent Series Resistance of Quartz Crystal Units by Zero Phase Technique in a Pi-Network*, Publication # 444, International Electrotechnical Commission, Geneva, 1973.

[4]Virgil E. Bottom, *The Theory and Design of Quartz Crystal Units*, McMurray Press, Abilene, TX, 1968. This is the "Bible" for quartz crystal resonator design, with concise coverage of all the equations and design considerations. That book has long been out of print, but I see two copies of a similar book by the same author currently listed as being available on **amazon.com**: *Introduction to Quartz Crystal Unit Design*, Van Nostrand Reinhold, NY, 1982.

[5]W. G. Cady, *Piezoelectricity; An Introduction to the Theory and Applications of Electromechanical Phenomena in Crystals*, (New revised edition in two volumes), Dover Publications, NY, 1964. This is the seminal work on piezoelectric crystals, based on the original research of Dr. Cady at Wesleyan University (Middletown, CT).

[6]*Fundamentals of Quartz Oscillators*, AN 200-2, Hewlett Packard Co. This application note includes a good introduction to quartz crystals and their use in oscillators. It is still available for download from the Agilent Web site: **www.agilent.com**.

Upcoming Conferences

ARRL/TAPR Digital Communications Conference

September 26-28, 2008

Chicago, IL

The conference location is the Holiday Inn Hotel, Elk Grove Village, IL.

The ARRL and TAPR Digital Communications Conference is an international forum for radio amateurs to meet, publish their work, and present new ideas and techniques. Presenters and attendees will have the opportunity to exchange ideas and learn about recent hardware and software advances, theories, experimental results, and practical applications. Topics include, but are not limited to:

- Software defined radio (SDR)
- Digital voice (D-Star, P25, WinDRM, FDMDV, DRMDV, G4GUO)
- Digital satellite communications
- Global position system
- Precise Timing
- Automatic Position Reporting System (APRS)
- Short messaging (a mode of APRS)
- Digital Signal Processing (DSP)
- HF digital modes
- Internet interoperability with Amateur Radio networks
- Spread spectrum
- IEEE 802.11 and other Part 15 license-exempt systems adaptable for Amateur Radio
- Using TCP/IP networking over Amateur Radio
- Mesh and peer to peer wireless networking
- Emergency and Homeland Defense backup digital communications in Amateur Radio
- Updates on AX.25 and other wireless networking protocols
- Topics that advanced the amateur radio art

This is a 3 day Conference, with technical and introductory sessions presented all day Friday and Saturday. Join others at the conference for a Friday evening social get together. The Saturday Evening Banquet will feature an invited speaker, and conclude with award presentations and prize drawings.

The ever-popular Sunday Seminar focuses on a topic and provides an in-depth four-hour presentation by an expert in the field. This year Phil Harman, VK6APH, presents "Software Radio Through the Looking-Glass." The presentation will be highly interactive, so be sure to bring along that SDR question that has been puzzling you for so long!

One-day only registration, Friday or Saturday is $45. Registration for both days is $80. The Sunday seminar is $25. Lunch both days and the Saturday Banquet are available at an additional cost.

For further details about the Conference, and for Conference registration information, see the TAPR Web page at **www.TAPR.org/dcc.htm**.

Microwave Update 2008

October 17-18, 2008

Bloomington, MN

Microwave Update 2008 will be held on Friday, October 17 through Saturday, October 18 in Bloomington, Minnesota.

This is a microwave conference, and presentations will be on topics for frequencies above 900 MHz. Examples of such topics include microwave theory, construction, communication, deployment, propagation, antennas, activity, transmitters, receivers, components, amplifiers, communication modes, LASER, software design tools, and practical experiences. Please contact Jon Platt, WØZQ, at **w0zq@aol.com** or Barry Malowanchuk, VE4MA, at **ve4ma@shaw.ca** for additional information.

2008 AMSAT North America Space Symposium

24-26 October 2008

Atlanta, Georgia

The Atlanta Radio Club announces that the 2008 AMSAT Space Symposium will be held at the Atlanta Buckhead Doubletree Hotel on Friday, October 24 through Sunday, October 26, 2008.

Call for Papers

Papers are solicited for the 2008 AMSAT Space Symposium and Annual Meeting.

Proposals for papers, symposium presentations, and poster presentations are invited on any topic of interest to the amateur satellite program. An emphasis for this year is an educational outreach to middle and high school students. Another topic if interest is using amateur satellite tracking systems to monitor deep space network objects.

In particular, papers on the following topics are solicited:

- Students and Education
- ARISS
- AO-51
- P3E
- Eagle
- Deep Space Network monitoring
- Any additional satellite-related topics.

We request a one-page abstract as soon as possible. Camera ready copy on paper or in electronic form will be due by September 1, 2008 for inclusion in the printed symposium proceedings. Papers received after this date may not be included in the printed proceedings.

Abstracts and papers should be sent to **n8fgv@amsat.org**.

Registration

Symposium registration is $40 prior to Sep 8, $45 after Sep 8 and $50 at the door. The Saturday evening banquet is $45.

QEX

In the Next Issue of QEX

George Murphy, VE3ERP, and Robert DeHoney describe a Dual Output Power Supply. DeHoney's innovative double bridge rectifier design provides nearly equal positive and negative dc output voltages with a common ground from a single ac power transformer. A conventional circuit using plus and minus half wave rectifiers presents some danger of saturating the transformer core, unless the positive and negative loads are carefully balanced. The double bridge rectifier eliminates that possibility.

George and Robert take us through the design calculations, and even offer a software solution to the math problem! If you work with dual supply op-amps or have other needs for equal positive and negative power supply output voltages, you will want to experiment with this circuit. Don't miss it!