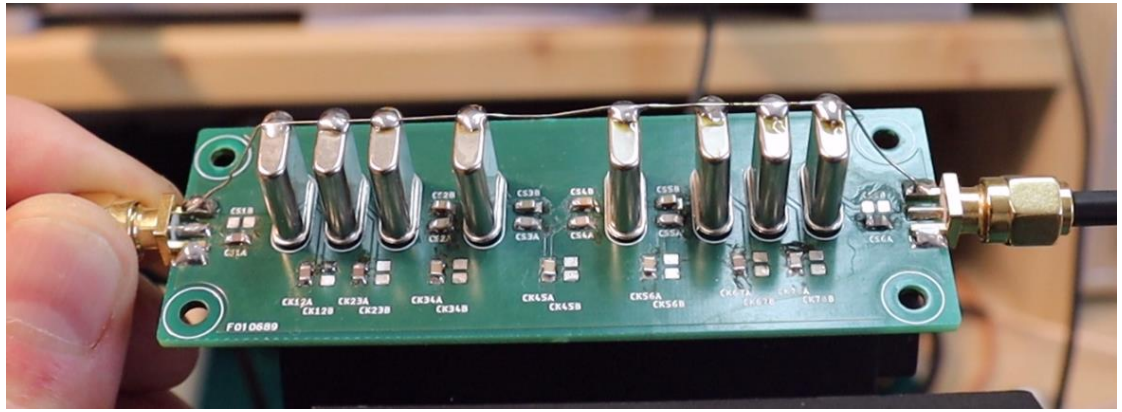
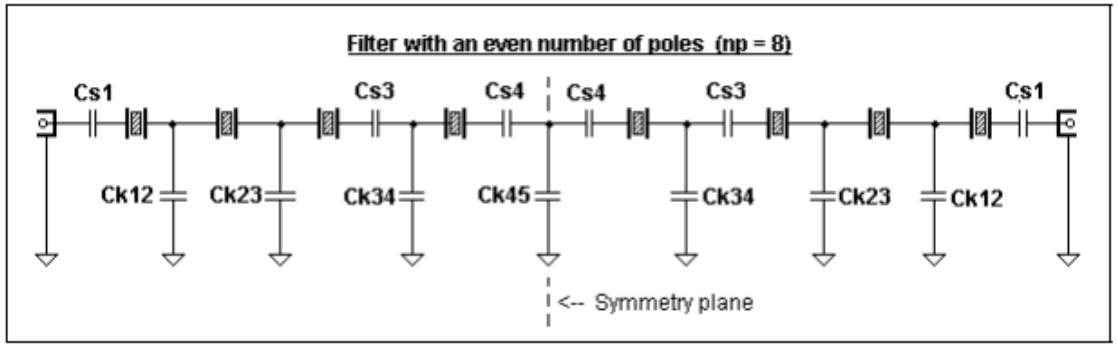
Crystal-Ladder-Filter design

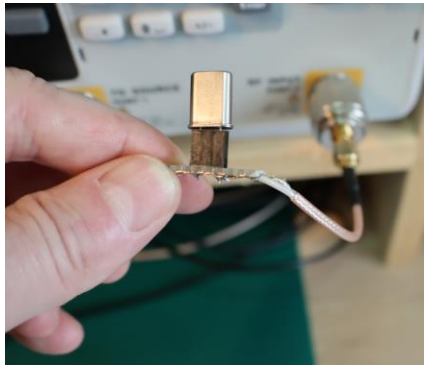
Crystal-Ladder-Filter have…
- very high Q
- very narrow band

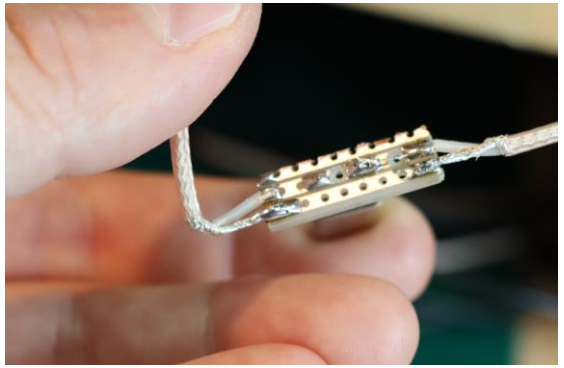
However, they…
- good only for a few kHz bandwidth
- only bandpass or bandstop
- not 50Ω
- crystal true replacement values (characteristics) are unknown
- need to select crystals

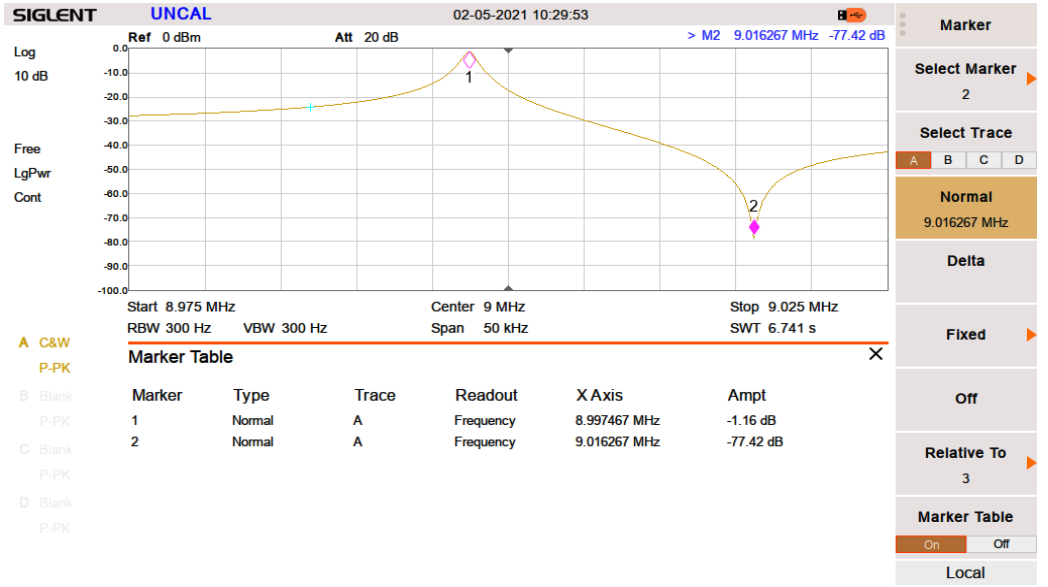


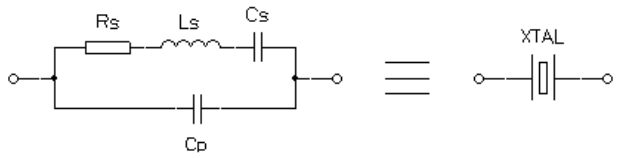


Characterizing Xtal

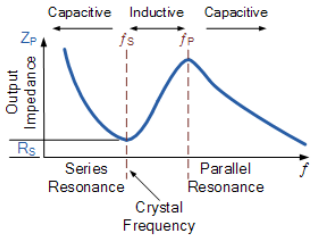








Cs: motional capacitance
Ls: motional inductance
Rs: series loss resistance
Rp: "holder" capacitance



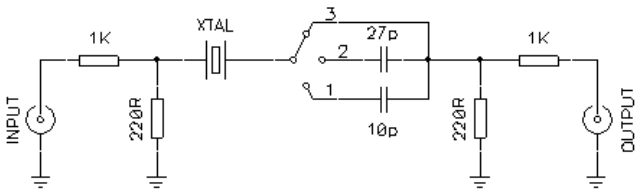
$$R = R \quad \text{and} \quad X_{LS} = 2\pi f L_S$$

$$X_{CS} = \frac{1}{2\pi f C_S} \quad \text{and} \quad X_{CP} = \frac{1}{2\pi f C_P}$$

$$Z_S = \sqrt{R_S^2 + \left(X_{LS} - X_{CS}\right)^2}$$

$$\therefore Z_P = \frac{Z_S \times X_{CP}}{Z_S + X_{CP}}$$

Cp measured with LCR meter: 5.3pF



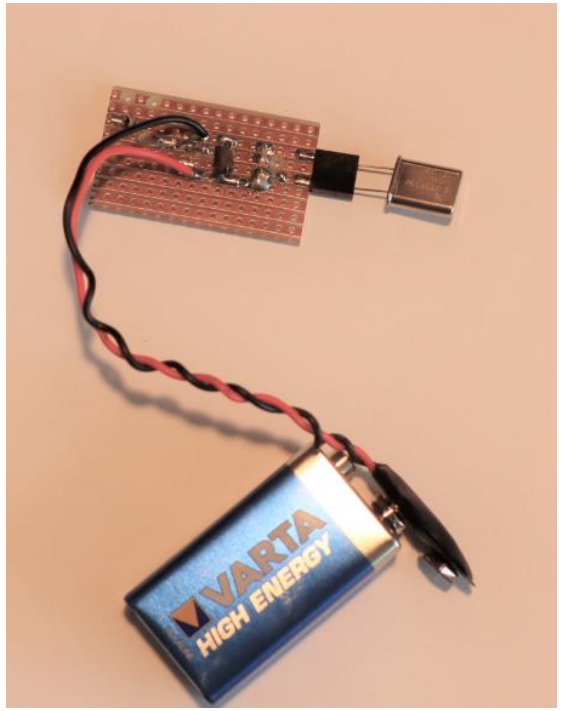
Crystal parallel resonance frequency: f_p =	9.016253	MHz
Crystal series resonance frequency (10 pF): f_{s1} =	9.002827	MHz
Crystal series resonance frequency (27 pF): f_{s2} =	9.000093	MHz
Crystal series resonance frequency (no capacitor): f_{s3} =	8.997387	MHz
Actual (measured) C1 capacitance: C_1 =	10	pF
Actual (measured) C2 capacitance: C_2 =	27	pF

Calculate

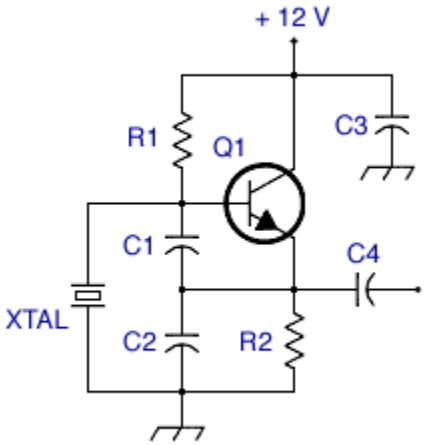
Crystal series capacitance: C_s =	20.347	fF
Crystal series inductance: L_s =	15.379	mH
Crystal parallel capacitance: C_p =	4.852	pF

https://www.giangrandi.org/electronics/crystalfilters/xtaltest.html

Selecting matching crystals to +- 50 Hz



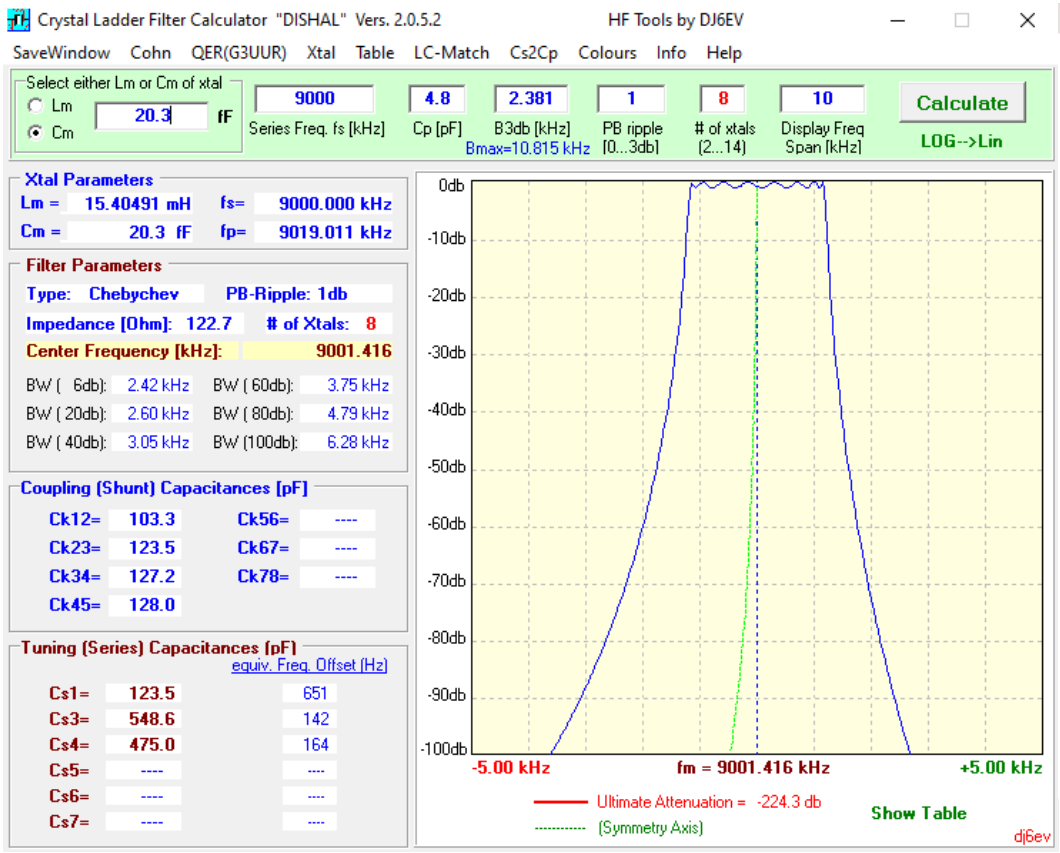
colpitts oscillator with 2N3904

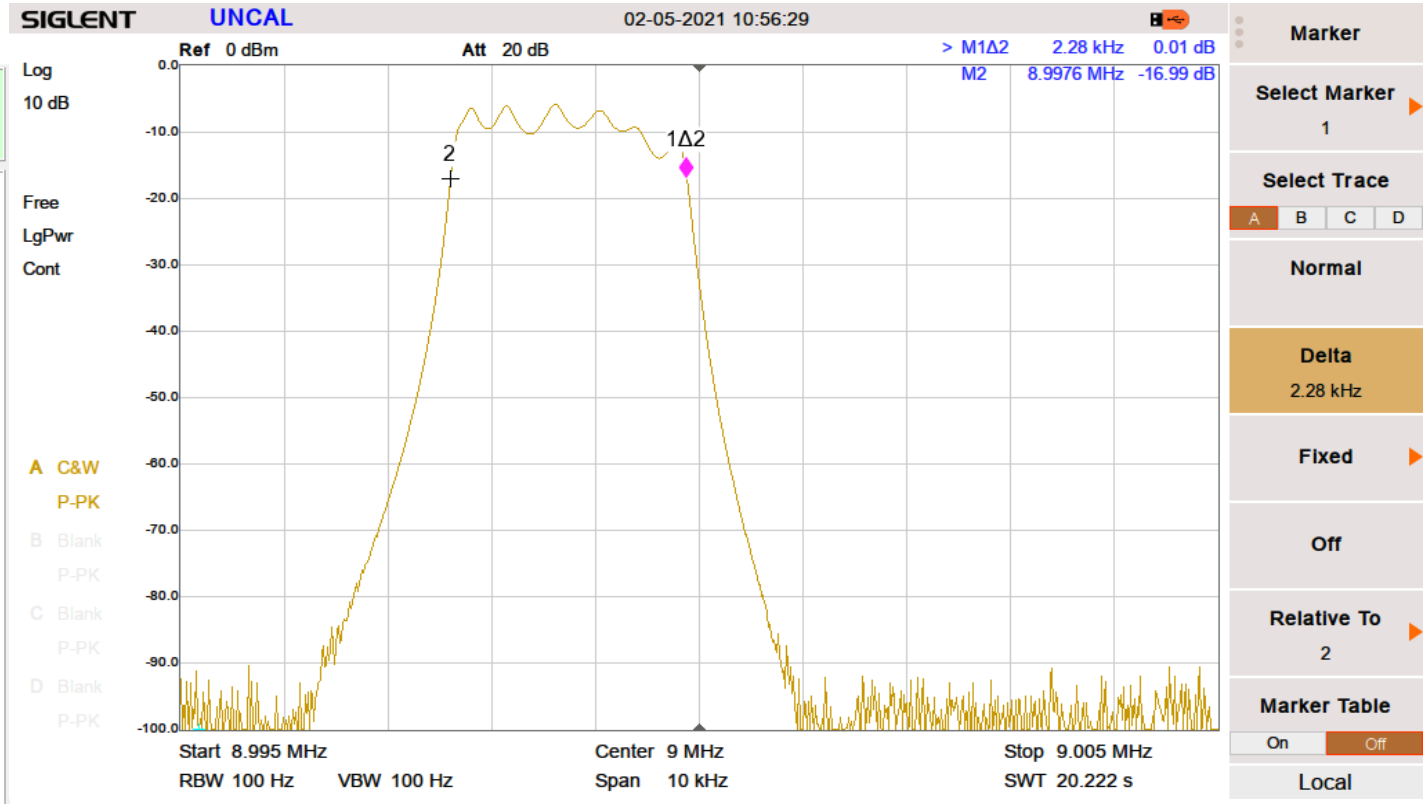


C1: 100 pF ceramic disc or silver mica
C2: 680 pF ceramic disc or silver mica
C3: .01 uF ceramic disc
C4: .001 uF ceramic disc
Q1: 2N3904
R1: 220 K
R2: 1 K

To the bench…

Dishal filter calculator and results





- additional tuning needed
- impedance matching